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ON THE SAFE ABOLITION OF PAIN

BY

ANÆSTHESIA WITH MIXED VAPOURS.

LONDON : PRINTED BY WILLIAM CLOWES AND SONS, STAMFORD STREET
AND CHARING CROSS.

ON THE

SAFE ABOLITION OF PAIN

IN

LABOUR AND SURGICAL OPERATIONS,

BY

ANÆSTHESIA WITH MIXED VAPOURS.

BY

ROBERT ELLIS,

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AUTHOR OF "DISEASE IN CHILDHOOD," ETC.

LONDON:
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PREFACE.

It must needs be superfluous for me to speak of the vast good which has arisen from the discovery of anæsthesia, whether by ether, or by chloroform. This little work was not designed for so trite a purpose. Neither has it been my object to advocate the use of one agent to the exclusion of others. My design has been to rob insensibility to pain of its terrors, and to remove its danger so far as, by any human device, that may be within compass of our art. The history of anæsthetics has unhappily a gloomy shadow to contrast with its long array of blessing and relief. That shadow is the occurrence of a sudden and unforeseen death to some of those who have applied to the discovery for immunity from a temporary pain.

Into the causes of this danger in anæsthesia I have thought it very unnecessary to enter, since these are fully discussed in other pages. They may be reduced, however, to a few simple heads, and are cursorily alluded to in this work. I take it for granted that there is danger in chloroformization, and indeed in every anæsthetic process, to a greater or less degree. I believe that the common sources of danger are due either to the agent, or to its mode of administration, or to both. I consider chloroform to have been toyed with in

many cases to a degree very significant of either great thoughtlessness or great ignorance as to its real powers; and it is certain that hence much undeserved dishonour has been put upon it. But it is also certain that this agent is, even with the greatest care, oftentimes too powerful for control when used alone, and I, therefore, advocate its use in combination with other vapours.

I have endeavoured to anticipate all the more common sources of danger in the anæsthetic process here indicated. By the mixed vapour method the depression resulting from pure chloroform is counteracted, and by my apparatus the precise dose is not only estimated, but, by a simple contrivance, rendered incapable of passing into excess. The practitioner has but to look on the face of his instrument to see what is the nature of the vapour he is administering to his patient; and this is so combined as to unite in itself a stimulant and a narcotic influence which are capable of alternation of intermixture and of relative adjustment with extreme facility and accuracy.

The system I have here advocated was briefly described in the *Lancet* for February 10th of this year, and some extracts from my paper in that journal, with an account of my original instrument, are given in the body of this book.

All subsequent experience of this method of abolishing pain has confirmed the hope then expressed that we had in it an easy, agreeable, and safe anæsthetic process. May such be the experience also of all the future.

ROBERT ELLIS.

63, *Sloane Street*, S.W.
March, 1866.

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CHAPTER I.

ON SOME DEFECTS OF EXISTING ANÆSTHETIC PROCESSES.

In common with many, perhaps the majority of the members of my profession, I share a feeling of insecurity, not to say dissatisfaction, in the use of unmixed chloroform for procuring insensibility to pain. I think probably few are in the habit of exhibiting chloroform, as it is now administered, without a sense of doubt as to the manner in which it will take effect on the person operated upon. The risk is, of course, small; all statistics go to exhibit that important and reassuring fact, but it exists notwithstanding, and I believe is due in great measure to the use of this anæsthetic agent pure and simple. Death by spasm and death by paralysis of the heart may probably be set down as the principal causes of a fatal issue arising out of the use of undiluted chloroform. Against other causes of death in anæsthesia, such as suffocation or coma, we can take precautions, and they may be successful; but against these two we have only a limited power to contend, so long as we continue to employ this powerful agent unassisted by other anæsthetics.

While engaged in obstetric practice it has long occurred to me how great would be the advantage of possessing a substance safe in the use, and at the same time capable of

producing insensibility to pain. Such an agent is yet to be found. But I think I have discovered a method by which the same result may be obtained by a combination, in a certain manner, of those substances with which we are already familiar. Reflecting on the commoner causes of fatal chloroform accidents, the conviction is impressed on me that we commence our anæsthetic induction with the wrong agency. Chloroform, however diluted, is unsuitable for the *early stages* of inhalation, and it is in these especially that fatal results have been most frequent. At this period the emotional causes of danger are most active, the resistance greatest, and the danger also greatest. When I have heard of a patient being rendered quite insensible in three minutes, it has always appeared to me—considering what must happen before insensibility can occur—that that particular patient has had a narrow escape. That all the natural emotion felt in submitting to an operation, with all its physical results, should be overwhelmed in this way, and the patient drowned in chloroform vapour in so rapid a manner, is in my opinion most unjustifiable and hazardous in no ordinary degree. But even when judiciously administered, chloroform, in my judgment, is the wrong thing to begin with. Its physiological action as a stimulant is brief, while its depressing effects are prolonged. Also, notwithstanding many assertions to the contrary, I think there is evidence to prove that in some constitutional conditions chloroform vapour acts as a depressant from the first. What it seems to me we require, therefore, is to commence the anæsthetic operation with some of those substances which will give a gentle stimulus to the patient, sustaining the heart-power, tranquillizing the emotional condition, and thus gradually introducing to the stage of first partial, and then complete, insensibility. In the method I have introduced this is effected by a means so simple and secure, that I

hope it may commend itself to the good opinion of many of our profession.

Especially in natural labour, in which pain is intermittent and generally very progressive in its character, it has appeared to me that chloroform has been in many cases much misused. For the earlier stages it is ordinarily quite unnecessary to do more than render the patient indifferent to the pain, while her consciousness is still spared to her. And only at the later periods of uterine effort, when the cruel agony of the expulsive pangs comes on, should it be proper to render her perfectly insensible. Now, if chloroform alone be used, and especially if it be administered in the common way—on a cloth, or by many of the ordinary inhalers—the patient can scarcely escape an overdose. There is in these appliances so little power of adjusting the quantity to the patient's condition, that at one time she will be seen heavily stupefied with the vapour, while at another she is crying out for the relief which it is only feebly affording her.

Then, certainly, the hazard is not small that by thus procuring anæsthesia, a large, even a dangerous dose, may be administered by any but a skilled hand. The nurse, if left in charge of the patient and the chloroform bottle, even for a short time, may very easily do mischief. A lamentable accident arising in this very way has, indeed, been communicated to me on very respectable authority. And if danger do not really arise, it is quite within ordinary experience that considerable inconveniences may occur, which may reach a degree not free from cause of anxiety and alarm.

The truth is, the agent is so extremely potent, and acts in such small doses, that it often misleads the medical man—and may, therefore, much more easily deceive the ignorant or unlearned. I hope to be able to prove, on another page, that there is no method of giving chloroform, except that

originally devised by the late Dr. Snow (that of charging a reservoir of air with chloroform in a determinate quantity),* now in use, from which an overdose may not easily be given, and that entirely without the knowledge of the administrator. I trust also to be able to show that by the simple apparatus which I employ, it is as impossible as in this original method of Dr. Snow, to give an overdose without the knowledge of the giver. The tell-tale finger attached to my instrument significantly acquaints the operator with the quantity and quality of the vapour which he is causing his patient to inspire.

The real power and depressing influences of chloroform appear scarcely to be fully recognized amongst us. I have elsewhere noted its special action, and its comparatives as contrasted with other anæsthetics. It is an agency of such inestimable pain-annulling properties that it seems almost ungracious to write of its dangers; but it certainly needs more careful handling, and my object is to prove its wider uses rather than to detract from its value. In combination, and in graduated and appreciable doses, it is without compare for the purposes of the accoucheur or the surgeon. Alone, and without control over the dose, it is too powerful for good or evil to be trusted to careless hands, or to be given in a careless manner.

There are probably few medical men, who have any experience in the giving of chloroform, who have not been witnesses of occasional symptoms of danger arising during the administration. One writer alone† states that he saw dangerous symptoms in *twenty-one* instances in his own experience! *Sixteen* of these occurred in cases where chloroform was given, as it is commonly given, on a handkerchief

* This ingenious idea has been practically carried out in the apparatus devised, and largely used, by Mr. Clover, with excellent results.

† Dr. Anstie.

or a napkin, and only five out of the number when a good inhaler was employed. It is therefore abundantly evident that the popular method of use is fraught with no little danger. But the still higher authority of the Committee on Chloroform, appointed by the Medico-Chirurgical Society, has proved that not less than 80 per cent. of the fatal accidents with chloroform have arisen when it has been given on a handkerchief, lint, or sponge. It might be thought that here lay sufficient cause for the abolition of a method of use so decidedly dangerous; but as yet no very decided impression has been made upon this hazardous practice, and the comparative impunity of the past has, in many cases, been taken to authorize the safety of this plan. It is, however, only too probable that a still larger proportion of the fatalities laid to the charge of chloroform, might more correctly be ascribed to the mode in which it was given. It is just as though a man, instead of moderately drinking of diluted brandy, took at a gulp a pint of the raw spirit and died from the shock.

It is very probable that the imperfections of most of the inhalers now in use have really been the principal cause of the persistence in the handkerchief mode of giving chloroform. The apparatus of Mr. Clover is the only one which has commended itself to the favourable judgment of our profession, from the simple reason that every dose given to the patient is of measured strength. Every other method hitherto practised fails in this, the most essential of all points. Snow's instrument, and all others which resemble it more or less, is as little to be relied upon for uniformity of action or regularity of dose as the napkin; and though these arrangements may offer a considerable opposition to the administration of a too powerful dose, there is not one of them which is constant in action, or which it would be safe to commit into the hands of an unskilled person. Their

radical defects are these: first, that they are charged with chloroform in successive doses, without due regard to the extent or condition of the evaporating surface. Ordinarily, the operator is merely told to fill the instrument loosely with blotting paper, or lint, as though the amount of surface given for vaporization were of no moment; thus, one instrument will give off five per cent. and another perhaps even more than that amount, according to the temperature and the surface exposed; and, secondly, they contain no provision for graduating the giving off of the chloroformized air. Their apertures of egress are always open and to the same degree. This is a most serious error—for the vapour of chloroform is dense, and may be poured almost like water from one vessel to another. It collects, therefore, in the frequent intermissions of chloroformization, at the bottom of the inhaler, and if that be a portable one, it flows in the recumbent position by actual gravity—and without inspiratory effort—into the mouth of the patient, and, if he be deeply narcotized, without exciting any resistance to its passage through the glottis. If the reader will make the experiment with any of these inhalers, and elevate the instrument to a higher level than the mouth, he will find in a few seconds a cold current of chloroform vapour pouring from it into his mouth. This particular objection of course does not apply to the form of Snow's inhaler, with the receptacle at the end of the elastic tube. But it applies forcibly to most of those which are immediately attached to the face-piece, and are held in the hand while administered to the patient. It is also specially applicable to the handkerchief method. And though the amount thus poured into the patient's lungs may be small in quantity, it must not be forgotten that it is highly saturated with the vapour,—and therefore equivalent to a much larger quantity in a more diluted state.

Chloroform, being a most potent narcotic, ought not to

be given except in an accurately-measured dose. What, it may be asked, would be thought of the physician who would permit morphia or hydrocyanic acid to be given in any but a carefully-estimated quantity? The balloon-apparatus, to which allusion has been made, certainly effects this with great nicety; but it is most inconvenient for practical use, from the great size of the reservoir of chloroformized air, and the instrument is costly, and liable to injury by constant use.

By either of the instruments which I have devised, and which are described on another page, this important object is most fully accomplished. By a very simple arrangement the fluid is supplied in a constant ratio over a determinate surface of evaporation, so that an excessive impregnation of vapour is really impossible, and an equable current of air, containing never more than from 2 to 3 per cent. only of chloroform, is constantly passing through the apparatus. And to guard against any undue collection of chloroform vapour in the instrument, if the chloroformization be intermitted for a short time, a graduated valve is placed, by aid of which the amount taken (for a few inspirations, until the excess be removed and the equilibrium restored) may be shaded off to a vanishing point. If only, therefore, as an apparatus for the giving of chloroform alone, a high degree of safety and utility may be claimed for this arrangement. But in its character as administering a compound vapour, its value and security will, I trust, hereafter be chiefly manifested.

It has been fully demonstrated by the Chloroform Committee, that of all methods of inducing anæsthesia, that by a MIXTURE OF VAPOURS offers the greatest advantages. It has been proved to be the safest, the pleasantest, and the best in its total results. Their report states:—

"One hundred and twenty-three cases have been col-

lected in which death could positively be assigned to the inhalation of chloroform. Even this large number is probably far short of the aggregate mortality which must have been due to its use in various parts of the world. Many of the deaths, moreover, happened during trivial operations, which, without chloroform, are not attended with risk to life. Added to these, there are cases still in which life is placed in imminent jeopardy during the administration of chloroform, although it is not actually lost. Facts so important have led the Committee to give their anxious attention to devise or adopt means for obviating such accidents.

"At times, even with every care, and *with the most exact dilution of the chloroform vapour, the state of insensibility may pass in a few moments into one of imminent death.* It is, therefore, extremely desirable to obtain an anæsthetic agent which shall be capable of producing the requisite insensibility, and yet is not so dangerous in its operation as chloroform. In the absence of any known substance possessing the required qualities, various mixtures of chloroform and ether have at different times been resorted to. It might be expected that a mixture of these bodies would combine most of the required properties, and be at once more active and compendious than ether, and less energetic than chloroform. The known differences in the actions of the two anæsthetics suggest that, in a mixture of them, the more dangerous properties of chloroform would be neutralized, or reduced by dilution. This might particularly be inferred from the influence which they respectively exert on the heart's action; the one (chloroform) depressing it almost from the first, the other (ether) sustaining, or but little diminishing, its force."

A description of several mixtures is then detailed in the Report, with some particulars as to their varying modes of

action. The substances used in these mixtures were simply alcohol, ether, and chloroform, the proportions varying in different cases. It was found that they were capable of producing complete insensibility in a little over the usual time in which chloroform alone acts, but with this remarkable difference, that the force of the heart was equably sustained all through. This was measured by the simple and ingenious instrument—the hæmadynamometer —in which the blood-pressure acts on a mercurial column, and accurately depicts its own rising or falling rate. It was found extremely difficult to destroy animal life by these mixed vapours, even when the air breathed by the animals was saturated with the vapour! and then only after a protracted inhalation. Even when the fatal result was thus procured, it was found that the heart continued to beat after respiration had ceased, so that had the subject been a human being, there would have been warning of danger, and possibility of recovery in due time.

"These mixtures," continues the Report, "exercised a much less depressing effect upon the action of the heart than chloroform alone. In this respect the mixtures appeared to combine the qualities both of ether and of chloroform; it being clear that at the same degree of insensibility the depression of the heart's action was less with either mixture than with chloroform.

"These considerations tend to establish the fact that a mixture of ether and chloroform is as effective as pure chloroform, and a safer agent when deep and prolonged anæsthesia is to be induced, while, at the same time, it is sufficiently rapid in its operation to be convenient for general use. It is quite possible that at some future time an anæsthetic may be discovered which will fulfil the required conditions yet more perfectly than either of these mixtures. In the mean time the Committee suggests that

they should be more extensively tried than they have hitherto been in this country."

The mixture recommended specially by the Committee was that containing alcohol one part, chloroform two parts, and ether three parts. These mixtures have been tried at some of the London hospitals in a sufficient number of cases to determine their value. But their use has not been continued; and notwithstanding this strong and clear testimony in their favour, chloroform alone continues to be administered for almost all, if not for all, surgical operations in public and in private practice in the metropolis.

It is probable that the reasons for their desuetude lie, among others, in the following inconveniences attending the use of these mixtures. First, the longer time which is required to obtain the requisite degree of insensibility, and the consequent difficulty of performing a number of operations within a reasonable limit. This, however, might be obviated (and probably with great advantage to the patient) by commencing the inhalation before he is brought into the operating theatre. In private practice the same objection cannot be urged, for no one could reasonably oppose the delay of a few minutes, when that delay is attended with much additional security. In the writer's opinion this very delay is all-important, for it is but too probable that fatalities have often happened from a too eager desire to see the patient quickly made unconscious.

The second great obstacle to the use of these, or any other anæsthetic mixtures, lies in the unequal evaporation of their various ingredients. This is a subject which will be fully discussed in the next chapter; but it may here be said, that this forms in reality a most serious objection, amounting even to a nuisance and inconvenience of no ordinary degree, when prolonged anæsthesia is to be provided for, or when, as in a hospital, one patient after another has to

employ the same inhaling apparatus. These substances evaporate, to a great degree, in the order of their volatility, the ether first, then the chloroform, and lastly (and very slowly) the alcohol. The water, of which there is always a percentage in both alcohol and ether, is left behind with the residual spirit, and the reservoir becomes charged with the dregs of preceding evaporations. These are often of a most offensive odour, for it is just at the last that these volatile fluids, if impure, give out their most disagreeable qualities. And the reservoir is choked with moisture, and thus unfitted for use until a fresh absorbing material is placed in it.

These objections have hitherto been fatal to the induction of anæsthesia by mixed vapours. And it can scarcely be matter of surprise that such should be the case. It is also by no means improbable that the impurities of commercial alcohol and ether have contributed their share to the abandonment of this most safe and valuable method; for it will be seen hereafter of how serious a nature these really are.

It might be thought that these obstacles would have been quickly overcome, the excellence of the method being so transparently evident and clearly demonstrated. It is, however, a fact, that they have hitherto remained as they are here described; and the happy immunity with which chloroform has often been given might seem to sanction its unmixed employ. Of late, however, a feeling of increasing doubt appears to have penetrated the professional mind; and it may be hoped it will result in the adoption of an anæsthetic process safer in its operation than chloroform, and equally blessed in its effects.

CHAPTER II.

ON THE VAPORIZATION OF ANÆSTHETIC FLUIDS.

It need scarcely be remarked that but for the swift vaporization of fluids possessing an anæsthetic property, their influence and usefulness would be greatly impaired, if not destroyed. If, for example, it were necessary to repeat the ancient practice of inhaling the fumes arising from burning substances in order to produce the narcosis which is necessary for the abolition of pain, it can be little doubted but that anæsthetics would be employed only in a very limited degree. The value of alcohol, ether, and chloroform, and of any other fluids used in this capacity, is greatly influenced by their respective volatility. The properties which these fluids possess in affecting the sensibility are, it is true, very different from each other, and bear only a modified relation to their rate of evaporation. But unless that were adequate at the ordinary atmospheric pressure and temperature to enable the air of an inhaler to take up a sufficient dose at each inhalation, however powerful the anæsthetic, its utility would diminish in proportion to its low property of vaporization. Thus, the fumes of the plant called *Lycoperdum Giganteum* produce a very safe anæsthesia, but in actual practice the difficulties of easily applying the agent have wholly interfered with its adoption. In like manner opium and Indian hemp might be employed, though not with equal safety, but their fixity of character forbids their convenient use.

The vaporization of anæsthetic fluids at ordinary temperatures becomes consequently of very great importance, and requires careful study. Especially does this become true when we consider the requirements necessary for anæsthesia by the vapours of several fluids blended together. In the Report of the Chloroform Committee it would appear that but a few experiments were made upon this important subject, and although that report so strongly urges the adoption of anæsthetic mixtures, it is evident that sufficient care was not exercised in determining the proper rates and order of evaporation of the constituents of these mixtures.

Thus, instead of using absolute alcohol, the alcohol really employed was of the specific gravity of 838; in other words, it contained not more than *eighty-four per cent.* of pure alcohol, the rest being water. The ether* also evidently contained a considerable percentage of alcohol, its specific gravity being as high as 735, that of pure ether not exceeding 720 or 725. The chloroform alone appears to have been good and pure. These facts would go far to vitiate any of the results obtained by the experiments of this committee, and it may here be said that such alcohol, and such ether, are not adapted for any experimental anæsthetic process, even if used separately, simply from the circumstance that they do not furnish a true standard of purity.

It is also very remarkable that in this report only a very indistinct allusion is made to a subject of vital consequence to the success of an anæsthetic mixture—namely, the equalisation of the rate of vaporization of its fluid elements. This is thus conveyed—"Ether is a more volatile fluid than chloroform, and in a mixture of the two the ether evaporates

* In the published Report occurs a curious error; the specific gravity of the ether, 735, having been given to the chloroform, and that of the latter, 1497, to the ether.

more quickly than the chloroform. The relative rate of evaporation of the two was observed by placing a known quantity on a cloth and exposing it to the air; it was then found that the percentage lost was, after exposure for—

3 minutes, ether 89 parts; chloroform 75 parts;
15 minutes, ether 93 parts; chloroform 85 parts.

The fact that the constituents of a mixture escape in somewhat unequal proportions, is proved by observing the specific gravity of the mixture before and after exposure, and it was found in all cases that after exposure the specific gravity was to a certain extent increased, proving ether had escaped before chloroform."*

The result, therefore, of this experiment goes to prove that if such a mixture were inhaled in any quantity, the percentage of chloroform would continue steadily to increase from the first, until, after protracted use, the inhaler would contain very much more chloroform than ether. This will more clearly appear from the experiments narrated further on. It can easily be understood how far such a result interferes with the protective powers exerted by the mixture—the proportion of the heart-stimulant steadily decreasing, and that of the heart-depressant constantly becoming more and more potent. In the writer's judgment this fact is to a great extent fatal to the use of anæsthetic mixtures in the fluid form, at any rate for obstetric purposes, or for hospital practice—cases in both which a considerable amount of the mixture passes through the inhaling apparatus.

In this same report no notice whatever is taken of the low vaporizing properties of the alcohol—and especially

* The experiments detailed further on throw very considerable doubt over the accuracy of these results, and appear to prove that the ether really escapes in a much larger proportion than that here given.

of such alcohol as was employed in the mixture, containing, as it did, not less than *sixteen per cent.* of water. A single drachm of the mixture recommended cannot be evaporated from a cloth without exhaling for nearly ten minutes after the chloroform and ether have vanished the characteristic odour of alcohol; and when this is dissipated the water still remains, sensibly *damping* the fabric: thus clearly showing the vast inequality in the vaporization of the different ingredients of this fluid. And, necessarily, as the quantity employed increases, so does this inequality become more and more obvious, until at length the absorbent material is quite wet with the heavier parts of the fluid—the more volatile parts of which have escaped before.

The consideration of these facts will furnish one very obvious reason for the small amount of favour with which these anæsthetic mixtures have been received by our profession. They also appear to justify a fresh inquiry into the subject. And although I cannot pretend to minute scientific accuracy in the investigations I have made in the spare moments of busy daily practice, it is hoped that for all practical purposes the results I have obtained are correct and will bear examination; at any rate they are comparable with each other, and some pains have been taken to give them a useful tendency. What is perhaps of the most consequence is, that they have led to an entirely new system of inducing anæsthesia, and that in public and private practice that method has been found to be most safe and effectual.

First, of the ALCOHOL. It was found almost impossible to procure really pure absolute alcohol, there being no commercial demand for such an article. The strongest commercial spirit was therefore taken, care being had that it contained no compound of methyl. This was first treated with carbonate of potash, and then drawn off and distilled

from fused chloride of calcium, and only three-fourths of the distillate was kept for use, the rest being thrown away. In this manner was obtained a very pure and delicate spirit, of a fresh agreeable odour, of a specific gravity of about 800 to 805, and possessing very volatile properties as compared with such alcohol as is described above. It contained, at specific gravity 800 to 801, little more than *two per cent.* of water.

Then, as to the ETHER. Commercial ether is fairly represented by the specimen employed by the Chloroform Committee, which had a specific gravity of 735. But the purest ether has a specific gravity of about 720. In order to obtain it in this condition, the best procurable commercial ether was well washed in distilled water, by which its alcohol was removed, and it was then drawn off and distilled from chloride of calcium, at a very moderate temperature, in a water bath. The fluid thus obtained had a specific gravity a little over 720, and was very pleasant to the smell, presenting in this respect a striking contrast to the commercial ether, the smell of which was acrid and pungent.

The CHLOROFORM was that prepared by Messrs. Duncan and Flockhart, from pure alcohol, and possessing a specific gravity of about 1495. It was fresh and agreeable to the smell, and may be taken as a good standard specimen of the best description of chloroform.

The specific gravities were ascertained with as much care as I had power to bestow, and were taken, and the experiments performed, at a general temperature of 60° Fahr., the barometric pressure being 30.

Thus the three most valued anæsthetic fluids were obtained in a state of definite purity. My object was not so much to obtain a standard of ideal excellence—for which purpose absolute ether and absolute alcohol in a chemical sense, and chloroform of still higher specific

gravity would have been requisite—as to deal with fluids which can easily be obtained with a little care for practical use, and of sufficient volatility and purity to answer the purpose of anæsthetic induction. Any operative chemist could without the least difficulty supply fluids of the quality described, by the gallon, for professional use.

It will be manifest, on consideration of the nature of the fluids thus obtained, that a series of good standard specimens was obtained of almost the highest volatilizing power, and therefore the best fitted for the composition of anæsthetic mixtures. If, therefore, the idea of combining these fluids into one mixture were a good working thought, we had here the best means of carrying it into operation.

In the first place, their comparative volatility at a temperature of 60° was ascertained in the following manner—a few drops of each fluid were passed up into the Torricellian vacuum of different barometer tubes, and the depression of the mercurial column carefully observed. The amount of vapour capable of being given off by the respective fluids at the temperature given, was thus read off at a glance—it being well understood that* "when a liquid evaporates into a vacuum the point of greatest density (of its vapour) is attained at once, while with a space filled with air some time elapses before this happens; the particles of air appear to oppose a sort of mechanical resistance to the rise of the vapour." In this way a ready estimate of the differing volatility of these three liquids were obtainable. The vapour of *Alcohol* was given off in such a quantity as to depress the column of mercury one inch and five-eighths. The vapour of *Chloroform* depressed the column in the adjoining tube to 6 inches. The vapour of *Ether* depressed it in a third tube 17½ inches.

It was thus rendered evident to the eye that at the same

* Fownes.

temperature these three fluids gave off vastly different measures of vapour—that afforded by the ether, for instance, being more than eight times as much as that given off by alcohol, and nearly three times that given off by chloroform; and, though it be certainly true that each of these liquids gives off vapour of varying tension at varying temperatures, the above may be taken as sufficiently accurate for the purpose of our comparison.

The effect of mixing these three fluids was tried, and the experiments yielded several very curious and interesting results. Into the barometer tube containing the alcohol, a few drops of chloroform were carefully introduced, and the fluids were mixed by agitation. The result was singular—the mercurial column only descended to 5 inches, instead of 6, which may be taken to represent the tension of the pure chloroform atmosphere. It was thus evident that the alcohol exercised a sort of restraint upon the volatilization of the chloroform to the extent of about an inch of the mercurial column.

Into the tube containing pure chloroform vapour, the depression being about 6 inches, a few drops of ether were introduced, and the fluids agitated together. Again, a singular result was observed—the depression of the column sank from 6 inches to 12 inches, or about only two-thirds of the full amount producible by ether alone. Thus proving that the mixed fluid resulting had a twice greater volatility than chloroform, and one-third less than that of ether.

Into the tube containing ether vapour, and standing at 17½ inches of depression, a little alcohol was introduced. The effect was equally remarkable—the mercurial column actually rose from 17½ inches to about 10. From which it was evident that over this fluid also the alcohol exercised an influence of restraint, reducing its volatility and the consequent tension of its vapour. That this influence was

really exerted by the alcohol was proved by another very striking experiment. A few drops of distilled water were passed into the combined alcohol and ether space, and the fluids well shaken. The effect was instantly to liberate the ether vapour so that it depressed the mercurial column once more to 17½ inches, showing that the water exercised over the alcohol in this combination the same property of solution and absorption which is noticeable in washing ether in the ordinary way.

I then found that some differences could be obtained by altering the proportion of the fluids mixed together. Thus, if the proportion of the ether were increased to two or three times that of the alcohol, an additional depression of about an inch or so was obtained; and this doubtless would occur in an increasing ratio if the experiment had been carried farther. As far as possible the experiments detailed were conducted with equal portions of the respective fluids employed.

It appeared desirable to test the tension in vacuo of the vapour of mixture A of the Chloroform Committee, and this was done as in the former experiments—the fluids being first mixed together in the proportions given, and then injected in a small quantity into the barometer tube. It is necessary, however, to remember that the ether and alcohol employed in this mixture were of a much higher standard of purity than that used by the Committee. The result was extremely curious—the mercurial column was depressed to the extent of 8½ inches, or, as nearly as possible, the half of that which would have arisen from ether alone. The mixture, therefore, *in vacuo*, possessed a volatility intermediate between that of alcohol and that of ether alone; and *theoretically* it would seem well adapted for its purpose. On injecting a little more ether the depression sunk to 12 inches. It is doubtless the alcohol, in great measure,

which affects the volatilization of this mixture, holding it in check to a considerable degree, but only so long, as will shortly appear, as the experiment is conducted in a confined and vacuous space.

The general conclusions which may fairly be drawn from these investigations is, that so far as *evaporation in vacuo* is concerned, a mixture of these volatile liquids possesses a different volatility from that of either of them separately, and might, therefore, seem to favour the theory of an anæsthetic mixture of uniform evaporation. But since the rate at which evaporation takes place in vacuo is not the same as that which occurs in the open air, it remained to examine the behaviour of the same substances under this condition—the condition in which, in fact, and in which alone, they are available for our practical employ.

The inquiry was thus prosecuted.* The anæsthetic mixture A of the Chloroform Committee, consisting of, by measure, alcohol one part, chloroform two parts, and ether three parts, was used, and ten drachms were put into a small retort. This was placed in a water-bath, kept at a temperature of 130° Fah. The specific gravity of the mixture was about 1000. After a lapse of twenty minutes a sample of the distillate was taken and carefully weighed, it was found to have a specific gravity of 900. In half an hour more another sample was taken, and the specific gravity of this specimen was found to be 1000. When all but about one fluid drachm was distilled, the specific gravity of the last sample had risen to 1100. On examining the

* The writer has a fear that he may be thought, from the text, to have conducted these simple experiments with all the rigid accuracy of philosophical investigation. Such was not the case. Though they are believed to be true representations of certain leading facts, they are not pretended to be more than this.

residue in the retort, it was found to be chiefly unevaporated alcohol, with a small quantity of water.

The examination of these products showed that the first sample consisted chiefly of ether and chloroform, with a mere trace of alcohol—the ether being greatly in preponderance. The specific gravity of pure ether being 720, and of chloroform 1495, and that of this sample 900, and the specimen being found to consist chiefly of ether and chloroform, it may be fairly concluded that the proportion of its ingredients was, of ether, little less than seven-eighths, and of chloroform one-eighth, with a trace of alcohol. In the second sample the proportions were reversed, and it consisted chiefly of chloroform and alcohol, with a little ether. From the third sample the very odour of ether was gone entirely, and it consisted of chloroform and alcohol in pretty equal proportions. In order to completely volatilize the two latter specimens, it was found necessary to increase the heat of the bath from 130° to nearly 200°.

Poured on a cloth, in order to test their powers of evaporation, the first of these samples at first exhaled chiefly ether, the vapour of which came off with some of the chloroform. Then, when this had evaporated, a strong odour of chloroform remained for a short time, and finally vanished, leaving only a faint *soupçon* of alcohol behind. The second sample lost its ether still more quickly; the odour of chloroform remained longer, and was more decided, and after its dissipation it left a very strong and characteristic smell of alcohol behind. The third sample had no odour of ether at all, smelt strongly of chloroform, and when that had vanished, a long-remaining smell of alcohol was left, which extended over several minutes.

When agitated in a test tube with distilled water, the first sample, which consisted chiefly of ether, with a small portion of chloroform, separated itself from the water, and

remained in a semi-transparent stratum, the water appearing to hinder the union of the ether and chloroform. The second and third samples became quite milky, showing, as in Mialhe's test, the blending of the alcohol and chloroform together.

To a fair extent, this gentle distillation of the anæsthetic mixture represents the order and sequence of volatilization of its different ingredients, and it proves that these ingredients escape from the mixture in that order which is indicated to us in another way—namely, by their differing boiling points. Thus ether, which is converted into vapour at below 96°, came off first; then chloroform, which boils at 141°, and lastly, alcohol, which boils at 172°. In all probability had the distillation been conducted at a lower temperature than that of the water-bath, 130°, the proportion of ether would have been found to be still higher than that given above.

Since, however, these fluids give off vapour at all temperatures, though in a very different ratio as to quantity and velocity, it was to be expected that in the distillates a portion of the three ingredients was discoverable. Even in the first a trace of alcohol, for example, was found present; but this does not affect the conclusion which must be arrived at—namely, that this anæsthetic mixture does not equally part with all its constituents, and that these must be arranged in very different proportions to perfectly effect this object.

It would no doubt be possible so to adjust the proportions of alcohol, chloroform, and ether as to obtain a mixture which would volatilize equally. But in order to effect this, it would be necessary to reduce greatly the proportions of the alcohol and chloroform, in order to render their alliance with their fugacious companion permanent. And the result of this would be that the properties of such

a mixture would so nearly resemble those of ether alone as to defeat the very purpose of these combinations.

The whole subject of the vaporization of these fluids in union, and of the behaviour of different combinations of them, is interesting, and deserves a far more careful study than could be given by the writer of this little book. The restraining influence of the alcoholic element over both ether and chloroform, so manifest in the barometric vacuum, appears to be almost—it is certainly not wholly lost when evaporation into air takes place. A precisely analogous influence is indeed exerted over the alcohol by water.

The vaporization of these anæsthetics into a vacuum, and on distillation at a very moderate temperature, having thus been glanced at, a few investigations were made into their evaporation at ordinary temperatures—as, in fact, it occurs for the practical purpose of inducing insensibility. At a temperature of 65°, half a drachm of ether alone was poured on a cloth about 4 inches long by 2 in width. It was completely dissipated at the expiration of ninety seconds. The same quantity of chloroform was poured upon a similar fabric, and it was found that nearly five minutes elapsed before it was all evaporated. A similar quantity of alcohol was then poured on the cloth, and nearly twelve minutes were consumed in its evaporation, and the lint was damp with a little unvaporized water. It was found that if *equal parts* of alcohol and ether were mixed together, the restraining influence of the alcohol over the volatility of the ether was very obvious. Fifteen minims of each being mixed together, and poured on the same cloth, it was found that the ether took longer in evaporating than when that fluid was used by itself. Thus it was nearly two minutes before all the ether was dissipated—the same quantity (15 minims) vanishing in seventy-five seconds when used alone. The residual alcohol occupied nine minutes in its evaporation.

The evaporation of the anæsthetic mixtures, A* and C, was now investigated. The temperature being 65° and the barometer at 30, a piece of lint of the same dimensions as before was used. Half a drachm of mixture A, weighing about 21 grains, was poured upon it. At the expiration of about seventy-five seconds all the ether had evaporated, with a little chloroform. At the end of four minutes all the chloroform was dissipated, with some of the alcohol; and there then remained on the fabric, alcohol (with a trace of water) to the amount of 2½ grains. At the expiration of six minutes this was reduced to 1½ grain. A second quantity, and a third, and a fourth of the same mixture were poured on the same cloth at intervals of about ten minutes, and it was found that after each sucessive dose the residual unevaporated fluid accumulated in the cloth to the amount of 1½ grains, or one-fourteenth of the total quantity each time.

The result of several experiments proved that—1, All the ether of the mixture, with a small portion of chloroform, and still less of alcohol, was exhaled in a little more than from sixty to seventy-five seconds; 2, That chloroform and alcohol, the former preponderating, continued to evaporate for three or four minutes more; 3, That the residual alcohol was dissipated in about one and a half or two minutes more; and 4, That a trace of water, with some alcohol, weighing in all about 1½ grains, was left in the cloth, making it sensibly damp to the touch.

Thus, out of the six or seven minutes occupied by the evaporation of the half drachm of fluid, the first was occupied chiefly by the ether, the next three by the chloroform, with a little alcohol, and the last by the alcohol alone. In

* It will be remembered that the anæsthetic mixture prepared with he fluids used in these experiments was of a nature much more favourable to its volatilization than that used by the Committee on Chloroform.

an inhaler, the patient would have breathed, for one-fifth of the time, chiefly the vapour of ether; for the next three-fifths, that of chloroform, with a little alcohol; and at last only the vapour of a minute quantity of alcohol. In all probability, as the doses were repeated, less and less alcohol would be inhaled, because of the constantly increasing accumulation of water (from both alcohol and ether), which would exert its attractive influence over that fluid, and so hinder its vaporization. It would be difficult to obtain a more clear expression of the uncertainty of anæsthetic mixtures in the fluid form than is found from a consideration of these experiments.

The mixture C, consisting of ether two parts and chloroform one part, was then tried. Half a drachm of this was employed over the same evaporating surface. At the expiration of from ninety to one hundred seconds, nearly all the ether had evaporated. From this to the end of three minutes, the evaporation of chloroform proceeded, and at the close of four minutes all had evaporated, a faint smell of alcohol being left behind for a few seconds—a result of some slight impurities in either ether or chloroform, or in both. Sixty minims were then used, and it was found that before the expiration of from two and a half to three minutes, all the ether had disappeared, and that from six to seven minutes elapsed before all the chloroform had evaporated.

This same mixture (C) of ether and chloroform was subjected to a gentle distillation at a temperature not exceeding 120°. The specific gravity of the mixture before distillation was 990. The distillate taken at the end of half an hour yielded a sample of specific gravity 910. The specific gravity of the liquid left in the retort was then taken, and it amounted to 1120. Thus in the clearest way showing the rapid volatilization of the ether and the slower evaporation of the chloroform. The first sample, mixed with

water, immediately separated into a clear *supernatant* layer, evidently consisting chiefly of ether, with some chloroform. The residual fluid, treated in the same way, exhibited the very opposite phenomenon—the *water* now being in a clear layer at the surface; thus proving that much of the heavy fluid at the bottom was unevaporated chloroform, mixed with some ether, thus affording a most decisive testimony to the fact I have been contending for—namely, the inequality of the vaporous exhalations of these anæsthetic mixtures.

It is true that the temperature of the inhaling apparatus sinks much below that of the surrounding air, and this must be remembered in considering the results here obtained. But in all probability the lower the temperature of evaporation, the more unequal would its effects become on these fluids, and a still larger difference in their relative proportions of escape would be manifested.

Before closing the present chapter, it may be fairly deduced, from the inquiry here detailed, that—

First. The ingredients of the anæsthetic mixtures evaporate in a great degree, independently of each other, and in extremely differing quantities.

Second. That though alcohol exerts, in vacuo, a powerful influence in restraining and equalizing their vaporization, this influence is in a great measure annulled on evaporation into free air, as in an inhaler.

Third. That the only method of obtaining a true anæsthetic mixture of fluids is by consideration of the respective volatility of its ingredients, and so adjusting their proportions as to provide that all should evaporate simultaneously.

Fourth. But as this can only be done by a very great reduction of the quantities employed, both of alcohol and chloroform, then the object of the mixture is entirely frustrated, and it is reduced in its properties to one similar to

ether only—the most volatile of the ingredients always taking precedence of the rest.

Fifth. That if impure alcohol and ether are used, these defects of unequal volatilization become still more exaggerated, and the result vitiated by the water left behind after evaporation.

Only a conviction of the real value of a mixture of anæsthetics would have induced me to discuss this subject at the length of the present chapter, or to have given the requisite time to its investigation in the numerous experiments from which these conclusions have been derived. But acting on a sincere belief that there lay a real power for good under the recommendation of the Chloroform Committee on this head, and that anæsthesia might be more safely induced by a definite mixture of the vapours of these three substances than by any other known means, I shall have obtained my object in demonstrating the fallacy of the method advised and hitherto practised, if it leads others to adopt a plan at once easy to put in practice, of a reasonable quickness in operation, and of as perfect safety in operation as can be conceived possible.

CHAPTER III.

ON THE PHYSIOLOGICAL INFLUENCE OF THE ANÆSTHETIC VAPOURS.

A DESCRIPTION of the method by which a successful combination of the vapours of these three valuable anæsthetics—alcohol, ether, and chloroform, and that in certain definite proportions—has been effected, might naturally follow the account given in the last chapter of the inefficiency of the mixtures in the fluid form. But it has seemed important, first, to show the grounds on which this system is recommendable, and the actual results of its employment on the human subject.

It is by no means universally admitted that there is any necessity for employing any other agent than chloroform for producing insensibility to pain. Notwithstanding strong evidence to the contrary, drawn alike from experience in the human subject, and from experiments upon animals, the peculiar danger of chloroform, used alone, continues to be denied. This resides in its depressing influence over the functions of the heart. It is said that nothing more is necessary to insure perfect safety than to provide, as in the apparatus already alluded to, a sufficient dilution of the vapour with atmospheric air; and, no doubt, to a considerable extent, this is true. But it is by no means universally true. "The energy," says the Report often already quoted, "with which chloroform acts, and the extent to which it depresses the force of the heart's action, render it necessary to exercise great caution in its administration, and also *suggests the ex-*

pediency of searching for other less objectionable anæsthetics." Such is the conclusion to which this Committee arrives as the result of a vast number of experimental researches, conducted by aid of the very apparatus in question.*

As it is chiefly with a view of avoiding this dangerous influence over the heart that the author's method of inducing anæsthesia has been devised, it is of consequence that the subject should be clearly investigated. The sources of danger in anæsthesia from chloroform are—1st. From its influence over the heart; 2nd, From its effects on the functions of the lungs; and, 3rd, From its action as a narcotic poison in the production of coma. The two latter sources of danger may arise either from the vapour of ether or, possibly, from that of alcohol, as well as from that of chloroform. They are, indeed, incident in a great measure to the anæsthetic process by any means carried on, if it be pushed to a great length, either of time or of impregnation with vapour. But the first and most important source of danger is almost wholly *peculiar to chloroform*, and does not apply in anything like the same degree to either ether or alcohol. On this point the evidence is most clear and irresistible.

To take a single experiment out of many—chloroform, in the proportion of only two-and-a-half per cent. (which is considerably less than the amount ordinarily given in inhalation), was administered by Mr. Clover's apparatus to a dog. The femoral artery was opened, and connected with the mercurial column of the hœmadynamometer. The animal's pulse beat 24 to the minute before the inhalation began, and the pressure of the blood rose in the hœmadynamometer to from 9 to 14 centimetres. In three minutes and a quarter the force of the pulse sank to 6 centimetres,

* The experiments with the more dilute forms of the vapour were conducted by means of Mr. Clover's apparatus.

or less than half the higher figure before chloroform was given. Up to fifteen minutes the force of the pulse oscillated between 5 and 7 centimetres. At seventeen and a half minutes it fell still lower—to 4 centimetres; and from this time continued steadily to fall, until at twenty-three minutes it fell as low as from 2 to 3. The heart ceased to beat at twenty-seven minutes, the hœmadynamometer still marking 2 centimetres at and after the death of the animal.

A small dog was then taken, and ether inhalation was given—but to the extent of not less than 14 per cent.—nearly *six times* the amount of the chloroform. The inhalation was continued at this strength for *twenty-two minutes*, without producing any marked effect on the force of the pulse. For another period of twenty-two minutes the pulse varied in force but little, oscillating from 9 to 12 centimetres. The breathing then stopped, and the animal began to die. Thus for forty-four minutes ether vapour of the strength of 14 per cent. can scarcely be said in any noteworthy degree to have depressed the pulse—killing the animal, in fact, chiefly by its effect on the respiration and not on the heart.*

The physiological conclusions which were deduced from many experiments similar to those here narrated, were as follows; it being premised that the analogy between the effects on animals and on man is sufficiently accurate and close to warrant the inferences arrived at:—

Chloroform at first increases the force of the heart's action,—this effect is slight and transient.

When complete anæsthesia is produced by chloroform, the heart in all cases acts with less than its natural force.

The *strongest* doses of chloroform vapour, when admitted

* Experiments 20 and 53, Chlorof. Com. Report.

freely into the lungs, destroy animal life by arresting the action of the heart.

By *moderate* doses of chloroform the action of the heart is much weakened for some time before death ensues; respiration generally, but not invariably, ceases before the action of the heart, and death is due both to the failure of the heart's action and to that of the respiratory function.

Contrasted with these conclusions as to the influence of chloroform, are those as to the effects of ether:—

The vapour of ether at first increases the force of the heart's action, and this effect is both greater and of longer duration than that observed with chloroform.

The stimulation is followed by a depression of the force of the heart's action; but at the same degree of insensibility, ether does not depress the action of the heart to the same extent as chloroform.

Ether destroys animal life partly by enfeebling the action of the heart—but chiefly by arresting the movements of respiration.*

It follows, therefore, if any reliance be placed upon these experiments—which were certainly conducted with much care and by most competent individuals—that the action of chloroform is specially to lower the heart's power, even in a weak dose, and that a sudden strong dose may paralyze the heart at once and destroy life. The influence of ether, on the other hand, appears to be directed chiefly upon the respiratory functions, and not upon these until after inhalation has been carried on to a very considerable extent. Nevertheless it is certainly true that a *slightly* depressing influence is exerted by ether over the heart.

* Chlorof. Com. Report, pp. 28, 29.

It is impossible to consider the different influences of these two agents without the occurrence of the suggestion that in proper combination they would neutralize each other—the ether furnishing to the heart the stimulus required to enable it to resist the action of the chloroform. And having regard to the well-known influence of alcohol, it would be a natural thought to add its stimulus to that of the ether, by which any depressing influence of the latter might be counteracted. Upon this principle the anæsthetic mixtures were devised; and though, as we have seen, there existed unsuspected sources of fallacy in the union of these differently volatile fluids, the general principle is not thereby affected, and the few experiments which were performed with them deserve due consideration. Had these experiments been carried on with an apparatus similar to that hereafter to be described, the results would doubtless have possessed a higher value and interest.

The Report states—"The mixtures A* and C were very similar to each other in their action. It was found in the human subject, as well as in animals, that insensibility might be induced by means of them with sufficient rapidity—that is to say, in four to eight minutes in animals, and in from ten to fifteen minutes in man. And further, it was ascertained, in animals, that inhalation of the vapour in a strong form might be continued for thirty or forty minutes without destroying life. In nearly all the experiments in which the animal was at length destroyed, the respiration ceased some little time before the heart's action. These mixtures exercised a much less depressing effect upon the action of the heart than chloroform alone—it being clear that at the same degree of insensi-

* This contained an intentional portion of alcohol; the other, C, also contained a considerable portion (unrecognized) in the impure ether which was used.

bility the depression of the heart's action was less with either mixture than with chloroform."*

The writer has endeavoured to state the case for and against chloroform, in contrast with the combined vapours, with fairness, and is unable to resist the strong conviction which its consideration has impressed upon him—namely, that until an anæsthetic shall be found, combining in itself all the properties of ether, chloroform, and alcohol, we possess in a vaporous union of these three agents all that is really required for safe and perfect anæsthesia.

But in obstetric use it has been said there is a greater tolerance of chloroform than in any other circumstance, and fatal accidents have scarcely been known, and it is therefore the less necessary to have recourse to any other or additional agency. In reply to this, out of the experience of twenty-nine different medical men, to whom the general issue was put as to the use of chloroform in labour, and its dangers, not fewer than six out of the number had observed the occurrence of unfavourable symptoms due to the employment of chloroform only. "Thus one writer remarks that he had seen no death, but great exhaustion; another had observed in two cases rigidity of the lower limbs, with a convulsive movement of the upper, and of the face, which made him fear convulsions, but all ceased on suspending the inhalation. A third had met with a few cases of induced intermission of the pulse, even under small doses of the vapour, and this had led him to prescribe a stimulant when the pulse is feeble. A fourth states that he had seen alarming faintness and swooning after delivery, without any hæmorrhage. A fifth remarks that in a few cases he had seen great prostration; and a sixth, that in a highly nervous woman, the anæsthesia caused slight convulsions of an hysterical nature.

* Report, p. 20.

and in another, who was very plethoric, a degree of coma, which required active depletion."*

These results are not to be regarded as inimical to the employment of chloroform in labour; but they clearly indicate its dangers and their remedy. Thus the "exhaustion," the "intermittent pulse," "alarming faintness," and "swooning after delivery," "great prostration," are all so many evidences of the depressing influence of chloroform over the heart. The "rigidity," the "tendency to convulsions," and the "coma," are probably due to the anæsthetic having been in the one case probably given insufficiently, and in the other, too deeply. It is very significant, however, and strongly confirmative of the necessity for allying a stimulant with chloroform, in labour, that five-eighths of these unfavourable symptoms were attributable solely to the effect of chloroform as a depressant, and would in all probability not have occurred had the anæsthesia been induced by the mixed vapours.

It is specially in parturition that the author's method of producing unconsciousness to pain is most valuable—as it was, in fact, expressly devised for this purpose. In a surgical operation the period during which anæsthesia is requisite can never be very prolonged, at longest seldom exceeds half an hour, and is often ended in a few minutes, or less; but in labour the case is very different. It must be here kept up, with greater or less power, sometimes for hours in succession; and especially in the most painful labours, where, from great tenderness or rigidity or contraction of the parts, the agony is the greatest—it is the most necessary and the most prolonged. Of how great importance, therefore, is it in such circumstances to keep up the strength and heart power of the patient, while the pain-annulling influence is maintained unabated. And by this means, and by this alone,

* Report, p. 111.

is it possible to combine these objects. These are not merely theoretical considerations; for it is well known that in many instances of prolonged anæsthesia in labour, and in long surgical operations, the practitioner is compelled to stop the chloroform for a time, and administer a stimulant in the form of wine or brandy in the interval. In the writer's method, the stimulant is given simultaneously with the anæsthetic; thus the power of the heart is sustained, while the sense of suffering is abolished.

To accomplish this object, I attach no little importance to the large amount of alcohol vapour which I administer to the patient. By the ordinary anæsthetic mixture of fluids, the experiments already detailed have shown the extremely minute (and lessening) proportion of this ingredient which can be administered by inhalation. Yet to this small proportion the Chloroform Committee evidently attach importance, since to their recommendation they append the opinion that "the alcohol which it contains probably stimulates and sustains the action of the heart."

In order to effect the vaporization of a sufficient quantity of alcohol to produce a sensible influence in inhalation, it became necessary to devise an entirely new arrangement within the inhaler. After trying a variety of different methods, it occurred to me to imitate the fringed arrangement of the gills of a fish, by which means, as is well known, a very large surface of action is exposed within a small compass. By means of a peculiar little framework within the instrument, over which narrow cambric frilling is stretched, a circular space, only three inches in depth and an inch and a quarter in diameter, affords nearly fifty square inches of evaporating surface, and is capable of most powerfully impregnating the air drawn through with the vapour of alcohol at the ordinary temperatures. So powerful is this arrangement, that it is pos-

sible to obtain from it air saturated with alcohol vapour, and almost incapable of taking up a larger quantity.

Air thus strongly impregnated with vaporous alcohol would of itself be capable of inducing a modified anæsthesia, if breathed for a sufficient time; but it is too slow in action to be of service for practical purposes. And it is also too irritating to the larynx, when used alone. In combination with a very small proportion of chloroform, and with the addition of ether vapour, it no longer acts as an irritant; and the union of these vapours constitutes an anæsthetic most agreeable and acceptable to almost every person to whom it has been given. It is difficult, indeed, to describe the sensations which distinguish its use, as contrasted with that of either pure ether or pure chloroform. But they seem to combine all the exhilarating effects of a stimulant with the soothing influence of a narcotic; and there is a remarkable absence of the deadly suffocating sensation which is often attributable to chloroform alone. These statements are not merely the result of a number of experiments which I have made in person, but are also derived from those to whom the mixed vapours have been administered, whether in labour or for surgical operations.

It is probable that the difficulty of procuring a sufficiently strong impregnation with the vapour of alcohol, by any apparatus hitherto used, has been a chief cause of its neglect in anæsthetic processes. Its vapour has, however, been used in experimental researches in the lower animals, and has been found capable of producing a complete anæsthesia, with profound and prolonged insensibility. One author states, in a recent work on chloroform,* "In my own experiments I have found that alcohol had the greatest effect in sustaining the heart's action during the influence of chloroform. I can particularly recollect one instance in

* Dr. Sansom.

which alcohol having been administered in vapour to a frog, it was impossible to cause death by any strength of chloroform vapour. I certainly think that a dilution of chloroform with alcohol is advisable in many instances, and I am qnite sure that the administration by the stomach of a little alcoholic stimulant acts beneficially."

Based upon a consideration of these facts, I have arranged this new method of producing anæsthesia. Having succeeded, by the arrangement alluded to, in securing any degree of saturation of air with alcoholic vapour, it became necessary to adjust to this the requisite proportion of other anæsthetics to make it at once safe, efficient in destroying pain, and reasonably rapid in operation. The alcohol vapour forms, in fact, the basis of this method, and the vehicle upon which are borne to the patient the small doses of ether and chloroform, which, united with it, produce the requisite degree of insensibility.

Before proceeding further it may be useful here to mention that air, however saturated with the vapour of one fluid, is not thereby disqualified for acting as the vehicle for the vapours of several others. Thus, if a glass jar be already filled with the vapour of alcohol, and a little fluid ether be placed in a saucer within it, the ether would vaporize into the alcoholic atmosphere without any difficulty. And again, if a little chloroform were poured afterwards into the saucer, that also would evaporate, and the result would be that the jar would contain a mixture of the three anæsthetics in a vaporous form. It is, therefore, strictly philosophical to arrange an anæsthetic formula which shall have either vapour for its basis, and yet be made the vehicle for carrying the others into the lungs of the patient. The combination of *fluids* of different volatility into one mixture, and administering the vapour of that mixture as a true representative of the fluid itself, has been already

proved to be erroneous, and liable to result in grave errors in practice. But the case is different in the method now introduced. Here the fluids are each kept distinct, and are caused to commingle only in the vaporous form. And, what is of greatest importance, the ratio between the proportions of each to the other is constantly kept uniform by a mechanical contrivance of great simplicity.

As will hereafter be made evident, the practitioner has here a method, by which he can administer to his patient an exact dose of the anæsthetic, be that alcohol, ether, or chloroform. He can vary that dose according to the requirements of his case; and only by palpable and self-condemned negligence can he administer an excessive dose—the mechanical index warning him of what he is about. In fact, as I have arranged it for general uses, it seems almost impossible to give a fatal dose of chloroform or ether by this apparatus, because the evaporating surfaces apportioned to these fluids have been so far reduced as not to permit the escape of more than three per cent. of either one vapour or the other, even when its apertures are open to the full.

In this new method, therefore, the vapour of alcohol constitutes the medium by which the more active anæsthetics are united and conveyed to the patient. An impregnation of from 1½ to 2 per cent. of alcohol vapour may be very constantly maintained by its means, and in practice has been found most convenient and agreeable in the use. A reference to the barometer experiments, alluded to on a preceding page, will show how important it is carefully to adjust the evaporating surfaces of the different anæsthetics, so as to keep up the same proportion between the vapour of a fluid of low vaporizing power, as alcohol, and one like ether, which has a volatility so many times greater. By no other than a mechanical arrangement was this difficulty to

be overcome; and that it has been completely overcome will probably be admitted by anyone who will take the trouble to examine the construction of the instrument and to test its performance. The case was simply this—ether escapes many times more rapidly than alcohol, as also does chloroform—the compensation is therefore to be found in reducing the evaporating surface of ether to its lowest point, of chloroform next, and then of enlarging that of alcohol until in a given time it threw off as much vapour from its larger surface as the more volatile fluids did from their limited area of exposure.

The patient may thus be said to be taking at each dose a true and definitely composed mixture of a general stimulant, such as is alcohol, and of a heart-stimulant, as in ether, and of the pain-destroying chloroform. And certainly if any one had a doubt as to the theoretic value of this method it would be dissipated on observing its excellent results at a confinement or operation.

One of the most singular and interesting results observable on putting this method into operation, is the abolition of pain without the entire loss of consciousness. But this, it may be said, is equally true of diluted chloroform. It is certain that occasionally such a result is found. It is on record, for instance, that a dentist took out one of his own teeth under such an influence, and without pain. But however possible such a condition may be, it is seldom indeed seen in actual practice. The boundary line, in chloroform inhalation, between consciousness and insensibility, is so sharply defined, that it is generally crossed without notice. And therefore, though it be a possible condition, it is a by no means usual one to see a patient in an anæsthetic state, and yet preserving his consciousness. The reason is indeed obvious, and is to be found in the wonderful potency of the agent, which causes that a few drops more in the inhaler—a

small percentage more of the vapour—puts the patient out of the domain of dreams into the stupor of unconsciousness.

On this new system, the condition of the person who breathes the vapour may be said to be literally under the finger of the operator. He may be kept simply a little excited, as with a glass or two of wine; a little turn of the regulator valve carries him over into a state in which the sense of pain is benumbed; by a little more it is destroyed; but his knowledge of what is happening is still pretty clear. Then comes the gentle sleep of full anæsthesia, and finally the complete and total loss of sensation and consciousness, in which state the most painful operations are gone through without a struggle of resistance.

Some experience is of course necessary to secure these gradations in the anæsthetic act. But the indications of the apparatus are very simple, and after a few times they may be understood by any medical man. The value of such a graduated power will be most felt in an ordinary labour. Here, at first, a very little of the alcohol and ether vapour is sufficient to give courage to the sufferer. Then, afterwards, as the "pains" increase in power, the valve is opened a little and a little more, until finally, as the last expulsive agonies arrive, the patient is no longer conscious of their occurrence, and only awakes to find her infant at her side. In an ordinary confinement, the greater part of the labour is thus passed through without destroying the consciousness of the mother, who may even be able dreamily to converse with her friends; until at its close all sense of pain and recognition of external objects cease for a short time, and the expulsive act is completed in this state.

I have employed this anæsthetic method in a number of cases in my own practice; and, in order to make it known to the members of our profession, at some public operations. Very general satisfaction has been expressed

at the results, which have been carefully watched. A few of these cases may be interesting as illustrations of the peculiar principles contended for in this little work.

The first case selected is that of an ordinary labour. The lady had never taken chloroform in previous confinements, but had been chloroformized for one of the minor operations. The vapour then appeared to disagree with her, and the anæsthesia was followed by a train of very unpleasant symptoms. It was difficult to get at the correct interpretation of this part of her history, as the medical attendant was abroad. He had, however, cautioned her never to take chloroform again; and, as may be easily conceived, she had some apprehensions as to the anæsthetic, which were shared by her friends. But her great dread of the pains of parturition induced her to consent to the employment of the mixed vapours. It was therefore extremely interesting to notice how she would go through this second chloroformization; it having been, in all probability, the depressing influence of the pure vapour which had previously been too severely felt by her. The result was most gratifying, and strikingly illustrative of the benefits of combining the stimulant with the anæsthetic.

She was allowed to hold the mouthpiece of the inhaler in her hand, and, the dilatation of the os uteri being rather painful, to take a few inspirations from the apparatus as the pains recurred. It was very singular to observe how entirely her fears of the whole act were now removed. The effect of the mixed alcoholic and etherial vapour (with barely a trace of chloroform) was to increase the volume and steady the character of her pulse, to give her strength for the fast recurring pains, and at the same time so completely to blunt the edge of them as to make her almost indifferent to their arrival. An hour was thus occupied, and in that interval the head had descended to the outlet,

and the more powerful expulsory pains began to make themselves felt. During this period there was scarcely a moment's loss of consciousness, it was a state rather of conscious indifference to pain, and she was perfectly aware of all that was occurring around her, and occasionally spoke. The index of the apparatus was kept steadily at a degree corresponding to certainly not more than from one-half to one per cent. of chloroform vapour.

But as the labour entered its third stage a little more chloroform was turned on—with the same facility as one would turn on the gas in a lamp. And from this time to the end, not more (and frequently less) than two per cent. was at any time allowed to pass through the inhaler. There was not any struggling, coughing, or resistance; she became unable to keep the instrument any longer applied to her face, and fell quietly asleep. The nurse was now placed in charge of the mouthpiece; the reservoir, with its index, lying under my observation and close to my hand, thus affording the most perfect control over the amount she was permitted to inhale. At no time was there any stertor or muscular rigidity, or any other evidence of the deeper action of chloroform. She remained quietly sleeping for about three quarters of an hour: the head was then born, the rest of the body quickly followed, and the vapour being now removed, she awoke in a few minutes, on hearing the cry of the infant, with the exclamation, "What! is the baby really born?"

It would be difficult to describe the feelings of thankfulness and relief which occupied the mind of this lady—dreading, as she had done, the pains of labour, and doubtful as to the suitableness of chloroform to her particular case. It was certainly a great satisfaction to settle this important point so clearly, and to prove that, given in combination, chloroform was no longer likely to disagree with her. Her

recovery was unusually good and rapid—better, in fact, than in any previous confinement.

To take another case, also of natural labour. In this instance the patient had borne one child previously, and had suffered such severe and protracted pain, that she looked forward to her next confinement with a species of horrible dread. In her first labour no chloroform was permitted to be given to her; and as there existed some contraction of the outlet, it may be readily imagined how severe her sufferings were—the child's head being unusually large. As in the instance just narrated, she was only allowed to breathe the alcohol and ether vapours, with a very faint trace of chloroform, for a considerable time. And, as in that case, during the whole of this period her consciousness was almost perfect. Contrasting her present indifference to the pains with her previous horror at the prospect of their arrival, it was amusing to hear her express her contempt for each as it recurred!

On the advent of the third stage of labour, the expulsive efforts became extremely powerful, and strong "pains" were really necessary to propel the child's head through the narrowed outlet. A larger proportion of chloroform vapour was now administered, in union, as before, with the mixed vapours. A gentle sleep came on, and was maintained to the close. The child born, the vapour was withdrawn, and in a very short time the patient awoke; the whole act of labour being completed by the voluntary expulsion of the placenta, within a few minutes after the birth. The whole event, which had in the prospect oppressed and terrified her, now appeared to her as a dream; in fact, a great part of it was a sort of waking dream, in which conscious effort was made, but without the experience of any sensation of distress. In the strongest pains, the proportion of chloroform vapour administered little, if at all, exceeded two

per cent. It is important to observe that, in neither of these cases was there any vomiting, or even a sense of nausea.

These two cases may be taken as good illustrations of the peculiar excellences of this mode of producing anæsthesia. The duration of the inhaling process in the first labour was about two hours and a half; that in the second was a little more than three hours. The amount of anæsthetic fluid used was in each instance so small, that it might almost seem incredible. In the first instance, from the commencement of inhaling to the birth of the child, it was, speaking roughly, of—

Alcohol,	sp. gr.	805	. . three drachms,
Ether	,,	725	. . four drachms,
Chloroform	,,	1495	. . *three drachms.*

In the second—

Alcohol (as above)		three drachms and a half,
Ether	,,	about four drachms and a half,
Chloroform	,,	*three drachms and a half.*

It is, of course, clearly understood that the inhalation was, as is always the case in confinements, intermittent; but in each case during the last hour the inhaled air was sufficiently impregnated with vapour to produce almost uninterrupted sleep of a quiet kind; and throughout, from first to last, the sense of pain was practically abolished.

There are, probably, no known instances in which so small a quantity of chloroform (in each case about three teaspoonfuls)* produced prolonged anæsthesia so completely, and effected its purpose so thoroughly, as those here narrated. Only for the extraction of a tooth, two or three drachms are frequently required: and many

* In one of these instances the quantity of chloroform employed was so small, in comparison with what she had ordinarily seen used, as to attract the attention and excite the surprise even of the nurse.

ounces are sometimes used in the anæsthesia of labour. No apparatus hitherto constructed is capable of showing such an extraordinary economy of force; and many are very wasteful, not to say perilous, in proportion to their waste. Of all other modes, probably the handkerchief or napkin is the most wasteful and the least safe.

No fact connected with chloroform administration is on clearer evidence than that, when given so as to produce deep insensibility, it will, in many instances, suspend both uterine contractions and the employment of the auxiliary powers of parturition. Even in a moderate degree, it occasionally protracts labour, by weakening the expulsive powers; although this, under due regulation, is an exceptional occurrence; while it is beyond question that, thus moderately given, it has a decidedly beneficial effect in promoting dilatation of the maternal passages. But given in combination, and in such extremely graduated doses as by the system here recommended, it is, in the first place, incapable of arresting these efforts, whether voluntary or involuntary; and in the next it appears, by giving a gentle stimulus, while it removes the painfulness of effort, really to facilitate and actually to shorten the duration of labour. In illustration, the following instance may be quoted:—

A lady, who had previously borne several children, and to whom chloroform had been refused, in consequence of a very decided medical opinion contravening its use, was attended by me in her last labour. She had previously suffered from disease of the rectum, for which she had undergone an operation; and, from her past experience in other confinements, looked forward to her next with no little dread, especially as there had been some return of her rectal ailment just previous to her labour. The pains of labour set in slowly, and were accompanied, as before, with great tenderness and sense of bearing down. They had

existed some hours before I was sent for. On arriving, the os was found fully dilated, at a little after three A.M., but the pains, though severely felt, were not very powerful in their expulsive character; they were evidently restrained in action, as is often the case, by the tenderness of the parts. She was induced, with a little unwillingness at first, to make trial of the mixed vapours of ether and alcohol, with scarcely any chloroform, and the effect on her pulse was observed. It was then found that there really existed no sufficient cause for fearing a fuller influence of the anæsthetic, and a larger proportion of chloroform was given in combination. The pulse gained in steadiness; the patient expressed herself as relieved from her distress, and feeling "deliciously comfortable." The pains became rapidly more powerful; and at a few minutes before four A.M. the child was born, certainly without suffering to the mother, whose surprise and thankfulness were very great at having passed the dreaded ordeal.

Here was a clear instance of a labour really assisted, and shortened by some hours, in consequence of the beneficial operation of the anæsthetics; for in all her previous confinements her pangs had been most acute and protracted. Observe, also, the extraordinary minuteness of the dose which accomplished this excellent result. It was found, on measurement, that, in the interval from a few minutes past three until a little before four o'clock, or little more than three quarters of an hour, she had used, of—

Alcohol,	sp. gr. 805	. .	half a drachm,
Ether	„ 725	. .	one drachm,
Chloroform	„ 1495	. .	one drachm.

These quantities may appear so small as to suggest the possibility of some error; but the writer can vouch for their accuracy. They represent, in fact, the true charac-

teristics of this system, as opposed to, or rather as contrasted with, that of ordinary chloroformization. It may be well understood, that a method of producing anæsthesia which kept up a greater or less degree of insensibility to pain for little short of an hour, at a consumption of not more than one teaspoonful of chloroform, with, say, twice that quantity of ether and alcohol, must have in itself all the elements of safety and efficiency in combination. But it may be asked, whether the immunity from pain was complete? The answer is best given in the patient's own expression of delightful comfort, until the last strong pains came on, when she was actually asleep, and only awoke at the cry of her infant. It may also be added, that no particular attempt to economize the anæsthetics was made in this or in any other of the cases which I have given; they were simply supplied to the apparatus exactly as it became nearly exhausted.

It is probable that about 400 cubic inches of air are used in the act of breathing in every minute—in five minutes, 2000 are consumed. Now, in order to produce an impregnation with chloroform of only two per cent., forty minims of the fluid would be required for every five minutes of respiration; and two per cent. is a lower impregnation than is ever used in ordinary anæsthetic processes. Mr. Clover's arrangement provides for a constant supply of air containing *more than twice this amount* of chloroform. The evaporation of the whole quantity of chloroform used in each of the cases first mentioned would, therefore, only yield sufficient air, charged with *not more than two per cent.* of vapour, to last for about twenty-three minutes of constant inhalation. Yet, in combination with a nearly equal proportion of the far less active fluids, alcohol and ether, this quantity was sufficient to carry the patient for some hours safely and painlessly through her confinement, from the commence-

ment of her sharper pains to the very birth of her infant. It would be difficult to adduce stronger evidence in favour of the system here recommended.

It only needs to consider the facts here stated to perceive wherein the real value of this method resides. It consists evidently in the dilution and diffusion of the chloroform, ether, and alcohol. The minuteness of the quantity of chloroform, conjoined with the stimulants associated with it, would quite account for the absence of depression, of vomiting, of stupor or coma, and of interference with the uterine "pains."

It may be said that these observations refer chiefly to the chloroform; but it must never be forgotten that the chloroform is, after all, the principal potential agent; the others are chiefly adjuvants; for, in the quantities administered, it is impossible that alone they could produce or sustain the anæsthetic effect so clearly and satisfactorily maintained in these typical instances to the degree obtained. It is most probable that these singular and interesting results of the influence of so small a quantity of anæsthetic fluids, are due to the influence rather of their combination in the mixed vapour, and to the dilution of the dose, than to the power possessed by either of itself. For in ordinary anæsthetic experiments, it has been found that about four drachms of ether are required to produce an effect equal to about twenty to twenty-four minims of chloroform; and a much greater proportion of alcohol is necessary. The influence cannot, therefore, have been due to the alcohol and ether *per se*, but chiefly to their action as vehicles and diluents of the chloroform.

A very analogous result occurs if a very small quantity of any stimulant, such as wine, be sipped. If, for example, an ounce and a half of wine be slowly swallowed, say by drops, or by sucking it through a fine tube, it is well known

that a speedy intoxication will be the consequence. Though taken in the ordinary way no such effect could be observed. I do not mean to assert that in a surgical operation there would not be a greater consumption of these fluids than is here indicated. This would be inevitable; first, because of the continued, not intermittent, consumption of the vapours; and, secondly, because in most surgical operations it is necessary to induce a state of more profound unconsciousness than in labour. But experience has shown that even in the most severe surgical operations, and reference may be made to a case detailed a little further on, in which it was necessary to perform a plastic operation on the anus, the consumption of the fluids is greatly below that used in any other process of inhalation whatever, it being possible to produce and maintain the deepest anæsthesia with only a very moderate amount of either of them.

Before closing this chapter, it may be interesting to advert to the use of this same apparatus and system of anæsthetics as applied to surgical practice, as well as to the relief of pain in parturition. For this purpose, I will briefly relate some results obtained with the rude apparatus constructed by myself, in the operations at St. George's Hospital, in January of the present year, and one or two cases selected from my own practice.

The case of a young lad was taken, who was to have a polypus removed from the nose. It was found difficult to procure a good inhalation in this instance, partly in consequence of a defect in the mouth-piece, and also because of the growth impeding free respiration. An anæsthetic condition was induced in about ten minutes; but only to the modified degree of abolishing sensation, without loss of consciousness. The operation was then performed; and, though the boy talked vehemently during its continuance, he afterwards acknowledged that he was quite insensible

to the infliction of any pain. The next instance was that of a middle-aged woman, on whom amputation below the knee was to be done. She became insensible in about eight minutes, and was ready for the surgeon in a minute or two more. In consequence of the severity of the operation, a deeper degree of anæsthesia was here necessary, and was readily attained. But after the division of the soft parts, the supply of chloroform vapour was turned partly off, and she breathed chiefly the mixed alcoholic and ethereal vapours, with a trace of chloroform. While thus respiring, she opened her eyes and looked round upon the surgeons, and at the walls of the operating theatre, in a sort of dreamy unconsciousness, without a trace of pain, and without the movement of a muscle of the face to indicate a knowledge that her limb was being severed. The gentleman appointed to anæsthetize the subjects for operation at the hospital expressed his surprise at a result so seldom to be observed when pure chloroform is employed.

A little girl of five years old was another case. In her, resection of the hip-joint was to be performed. The child, without a struggle, took the vapours, fell asleep without resistance, and, during a rather long operation, was kept alternately breathing the mixture of vapours without and with chloroform, entirely without sensation. An interesting case was that of a delicate young man, who was suffering from extensive scrofulous disease of the os calcis and adjoining bones. For their removal a tedious (under other conditions a painful) and exhausting operation was required, and a good deal of blood was unavoidably lost. He became unconscious in eight minutes, breathing a mixture of equal parts of chloroform vapour, alcohol, and ether. His pulse was fairly sustained throughout; and when it occasionally flickered, the chloroform was turned aside, and the heart-stimulants alone were respired. In less tha

one minute the heart felt the excitant, and the pulse steadied and became full again. This occurred several times, and was distinctly observed by the gentleman above alluded to and by myself.

The next case is that of a lady, upon whom I had to perform an operation of a plastic nature, in order to restore a portion of the anus lost by sloughing. She had previously taken chloroform several times, and the smell of the vapour had become so repulsive to her as to be almost insupportable. The chloroform had also produced much struggling, excitement, and resistance. She was thankful to be assured that this time she would not be aware of its presence. She was given to breathe, for a space of about five minutes,. a mixture of alcohol and ether only. At the end of this time she was beginning quietly to fall asleep—without the least resistance or excitement. A very little chloroform was then turned on, and this was steadily increased until, in about ten minutes, she was inhaling an equal mixture of all the vapours. She was now quite unconscious, and lay perfectly still as if in profound sleep—it being very necessary to procure deep insensibility for the painful operation in question. She was sustained at this degree of anæsthesia during the necessary steps for the restoration of the anal margin, quickly recovered consciousness after completion of the operation, and made a good and rapid recovery. It was singular to observe that the smell of the mixed vapours was rather agreeable to her than otherwise, and she was thus insensibly introduceed to the, to her, more repugnant chloroform vapour.*

* In this case I succeeded in forming, out of the few fibres of the sphincter still left to the patient, a most excellent and serviceable termination to the rectum, with efficient control over the bowel—which had been lost for many years.

Not to add to these cases unnecessarily, the last which may be quoted is that of a gentleman nearly eighty years of age, suffering from a polypoid growth from the rectum, and from internal piles. For the cure of these, which bled so profusely as seriously to threaten the patient's life, the ligature was necessary. In a previous operation for carbuncle, I had in vain tried to bring him under the influence of chloroform, given by an ordinary inhaler, and it was necessary then to discontinue it and to operate on him while still sensible. The chloroform appeared really to disagree with him. This was therefore a good case for testing the applicability of the mixed vapour system. The inhalation was commenced with alcohol and ether only, and continued for a considerable time; then a little chloroform vapour was added, and a little more, in regular doses of increase, until they reached about three per cent. There was some resistance at first, and a surprising power of "coming to;" but at length the constant gentle doses of the vapours quieted down all excitement, and the patient being quite unconscious, I passed a double ligature through the diseased growths, and the operation was over in a few minutes. From my experience of this gentleman's case, I have a very strong conviction that had the attempt been made to render him unconscious with chloroform alone—for which purpose a powerful dose must have been given—symptoms of a very uncomfortable, if not alarming character, would have made themselves manifest. His was one of the exceptional cases in which, from some inexplicable cause, the influence of pure chloroform appears really deleterious, if not poisonous. It may therefore fairly be claimed as a success for the system here sought to be introduced.

CHAPTER IV.

OF THE FLUIDS AND APPARATUS EMPLOYED FOR THE MIXED VAPOURS.

One of the obstacles to the employment of alcohol and ether as anæsthetics has been the great impurity of these liquids as found in ordinary pharmacy, and especially of late, since the permission for the manufacture of methylated spirits by the Excise. The same impurity—the presence of various compounds of methyl—is equally to be found in a majority of the specimens of commercial chloroform; but the more powerful odour and pungency of its vapour more completely conceals the adulteration. Especially to the use of ether has the objection been made as to its unpleasant odour; but this, as will immediately appear, is not by any means its real characteristic; it is rather the result either of intentional adulteration or of accidental decomposition. It being of the first importance to determine the best kinds of the anæsthetic fluids for use in the system now advocated, I will precede my account of the instruments I employ with a short description of the simple means by which these fluids may be had pure and fit for use.

The most common impurity of all, and one which, unfortunately, is almost incapable of removal, is the addition of methyl, or its allies, to the alcohol, which is the basis of these anæsthetic fluids, in order, for excise purposes, to render the spirit no longer potable. The object of the manufacturer is, of course, to avoid payment of the heavy

duty on pure alcohol, the vitiated spirit being consequently employed on account of its cheapness. I believe that methyl in any anæsthetic renders it not only unfit for use for inhalation, from its filthy and disgusting odour, but likewise has a tendency to produce headache and other discomforts. The presence of this substance in minute quantities is often unnoticed, even by medical men, for the manufacturers often succeed, by some art of distillation, in reducing the quantity present almost to a minimum. A short time ago some chloroform supplied from one of the most eminent firms of operative chemists, and labelled "Pure chloroform," was given to me for use in hospital. It was found to be contaminated very decidedly with methyl, but not to a degree sufficient to have caught the notice of the surgeon who had used it.

As there is no simple method possible by which this substance can be thoroughly purged from either alcohol, ether, or chloroform, the medical man is recommended to return the sample in which it is found, as unfit for use. Its presence, even in very small quantities, may be readily ascertained by the old device, made familiar to us in discovering the true Eau de Cologne from its imitation, namely, by pouring a few drops of the suspected fluid on the hand—preferably on the back of the hand rather than into the palm—and then, when all is evaporated, breathing over the surface and smelling it. The peculiar faint repulsive odour of the methyl adulteration comes out immediately if it has been present in the spirit, whether alcohol, ether, or chloroform. If no trace of odour be left behind, the spirit may be deemed pure. No better or simpler test than this can be found, and it is perfectly reliable if the surgeon will only once learn to distinguish the pure from the impure specimens.

Pure non-methylated alcohol may be readily obtained

from any respectable chemist, if it be specially asked for. But this alcohol will be found generally very unfit for inhaling, from its high specific gravity, and the consequent feeble volatility it will possess. What is sold as "absolute" alcohol will be found to contain from 16 to 18 per cent. of water, or even more. The most easy method of ascertaining this is to take the specific gravity. Unfortunately there is a too general impression about this simple business that it cannot be done but by a good operator, and with aid of a very finely-adjusted balance. No doubt for extreme accuracy this may be necessary; but for practical purposes I have found it quite sufficient to take any good balance, turning with a quarter or a sixth of a grain; then to get a small, long, thin glass bottle, made of tubing, or a very small test tube itself would answer, and (at ordinary temperature, 60°, and barometer at or near 30) accurately weigh it, first empty, and then filled with precisely 100 grains of distilled water. The level at which the water stands is then carefully scratched with a file; or two lines may be scratched, one at the upper edge of the slightly concave surface of the water, the other at the lower; and the exact centre between these represents the proper height for future experiments. We have now got an excellent specific gravity bottle, quite accurate enough for our purpose. A quantity of either alcohol, ether, or chloroform, which will fill this little bottle so that its level precisely stands in the interspace between these two lines, is, with the proper counterpoise of the glass bottle, put into the balance and weighed. Thus, if it be alcohol, this quantity ought not to weigh more than 80, or at most 81 grains; if it be ether, it should not weigh more than 72 grains; and if chloroform, it ought to weigh at least, and more properly it should exceed, 149 grains. Thus, with a very little care, any medical man may get a most excellent

standard by which he can gauge the quality of the fluids he employs. To get the true specific gravity (pure water being 1000) it is only necessary to multiply these figures by 10. The balance ought to turn at least with a quarter of a grain, since every grain stands for 10 in estimating the absolute specific gravity of the fluid.*

It may probably save much trouble if the alcohol and ether are procured by a special order from some of the clever operative chemists, of whom there are several in London. The practitioner cannot spare the time to be rectifying his anæsthetic fluids, although he may be glad to have a simple and ready method, like that above, for ascertaining their fitness for his use. But it may not be out of place if I proceed to describe the very easy way by which both of these fluids may be procured in a most excellent condition for inhaling.

Alcohol of great volatility, and of specific gravity little exceeding 800, may be thus obtained:—the best rectified spirit must be taken; to one pint of this must be added about three or four ounces of carbonate of potash (not bicarbonate) and well shaken in a stoppered bottle. The attraction of the salt for water soon dissolves it out of the spirit, and in a couple of days the carbonate of potash lies in a heavy semi-fluid state at the bottom of the bottle, leaving the alcohol in a clear supernatant layer above. The alcohol may then be drawn off by a syphon into a retort—a large Florence flask, quite clean, will answer. A couple of ounces of coarsely-powdered fused chloride of calcium must be put into the flask, and the whole well shaken, and connection made by a glass tube with a receiver—say another glass

* The ordinary specific gravity bottle, holding 1000 grains of distilled water, is of course still more convenient; but it is often a point of importance to take the specific gravities of only small quantities, such as one or two drachms of fluid, in which case this bottle is too large for use.

bottle, plunged to its neck in ice-cold water. The body of the flask is then immersed in a pan of hot water, which may be kept nearly boiling by a gas flame or spirit lamp. In a short time the alcohol comes quietly over, and when three-fourths are distilled off, the process may be discontinued, and the distilled product is fit for use. If this has been conducted with care, the specific gravity will be about 800 —it may be even less; but, as has been before remarked, at 800, there is only present two per cent. of water, and the spirit is quite sufficiently good for every practical purpose.

Commercial sulphuric ether is generally a very unpleasant liquid, even when it has been made from pure alcohol. It has a rank, acrid, pungent odour, and this has brought the fluid into much professional disfavour; but such characteristics are by no means necessary to the ether, they represent, in fact, its impurities. It is a remarkable fact that ether, if it be long kept, undergoes some peculiar kind of decomposition, the nature and products of which are not distinctly known, and as one result of this decomposition, the disagreeable odour is evolved. But quite pure and perfectly fresh ether has not by any means an unpleasant smell. Many persons prefer it even to chloroform, which, if it has once been inhaled, leaves often a peculiar repugnance to its smell behind; and there is this very singular fact about ether in inhalation, namely, that whereas chloroform induces a sensation which makes the patient refuse to continue to take it, pure ether, on the contrary, seems to produce the very opposite effect, and the person who inhales it feels as though he could never take in enough of it.

Commercial sulphuric ether of the best kind may be made fit for inhaling in the following manner :—It must be mixed with equal parts of pure distilled water, and frequently agitated. By this means some of the impurities

acquired by keeping, and almost all the alcohol, are removed from it. The pure ether lies on the surface of the water, and may be drawn off by a syphon. It should then be placed in a flask, to which, for a pint of ether, an ounce of pulverized caustic potash is added, and frequently shaken. After allowing it to remain in contact with the potash for a few hours, the ether, which has now probably become of a pale yellow colour, owing to the decomposition of some portion of its constituent impurities, is to be transferred to a retort. This, when placed in a pan of water heated to about 160° to 180°, will readily distil off, and may be collected as before. It should have a specific gravity ranging from 720 to 725; if it be higher than this, it is because it contains alcohol, but if the plan here recommended be carefully observed, the product is sure to be of good quality, and extremely energetic as an anæsthetic agent.

In order to keep ether thus obtained in a condition fit for use, it should be entirely shut out from access to atmospheric air. The bottle should be kept, carefully capped and stoppered, in a cool cellar, and in the dark. Thus preserved, it will remain quite good for several months, but after that it will require redistillation. It must not, of course, be forgotten that it is a very inflammable liquid, and care will be taken as to lights being brought near to the bottle. Its dense vapour is very inflammable also, and will easily take fire if a quantity of the liquid be poured from one bottle into another too near a flame. When perfectly freshly distilled the liquid has a very agreeable aromatic odour, much less fatiguing, if I may use such a term, to the sense of smell than that of chloroform, and less irritating than that of alcohol. Much has been said by different authors as to the unpleasantness of the odour of ether, and its consequent inferiority to chloroform; but this may be readily accounted for from the fact that none of them have taken the trouble

to prepare for themselves a perfectly pure and fresh specimen, having used only the deteriorated samples of the shops. My experience of its use has been very extensive in combination with alcohol, and I have never yet heard any complaint as to the odour of the vapour.

In order, however, to remove this as a possible objection to anæsthesia by the mixed vapours, it is easy to communicate an agreeable odour to either the alcohol, or the ether, or both. This is best effected by adding to an ounce bottle containing that quantity of either liquid, a few drops of volatile oil of nutmeg, and about half the quantity of oil of lemons. These are the ingredients which give to sal-volatile its refreshing odour, and after much trial with these and other substances, I prefer this admixture to all other aromatics. It is also my opinion that they effect a slight good in reducing the tendency to sickness after chloroform; and they certainly render the anæsthetics very agreeable to the smell. The perfumes are not suitable for this purpose; even the best, such as Eau de Cologne, communicate a sense of nausea if inhaled for any considerable time. For the curious on this very minor point, it might be worth a trial whether the air drawn over fresh flowers, of which a few might be laid on the air passages of the inhaler, would be acceptable to the smell. But my own opinion is, that aromatic substances are, after all, the best adapted and the most easily applied for this purpose.

In order to prevent any possible mistake, it is advisable to give a little colour to both the alcohol and the ether. This is readily effected by adding to each bottle a few drops of an alcoholic tincture of brazil chips, or of the alkanet root. It is convenient to give a mere tinge of colour to the alcohol, and a deeper red to the ether. They are thus easily distinguished from each other and from the chloroform.

Of the chloroform, there is little to be said. I have never used any other than that of Messrs. Duncan and Flockhart, and have always found it so extremely good and pure, that it would be vain to seek to amend it. But since others may employ samples from different makers, it is right to mention that there are many impurities incident to this substance, which should receive the careful notice of the surgeon, but which will be found fully detailed in the handbooks on chloroform administration. Of these the most pernicious is free chlorine—which is readily discovered by immersing a piece of litmus paper, which in a few hours becomes quite white. In a sample recently sent to me for my obstetric use, by a highly respectable firm, in mistake for that made in Edinburgh, the acrid fumes of chlorine were so decidedly noticeable, that the bottle was sent back unused.

It may be convenient to add, that so great is the economy of the fluids in the apparatus used, that bottles holding small quantities of each will be found quite sufficient for any ordinary case, such as a confinement, and still less for an ordinary surgical operation. "More than a pint of ether,"* writes a recent author, "is sometimes requisite to produce and sustain the insensibility necessary for an operation!" But in the system here advocated, this monstrous allowance is out of all question. For an ordinary confinement, the probable amount of each fluid which will be used *per hour*, is pretty nearly of alcohol from 60 to 90 minims; of ether, about 90 to 100 minims; and of chloroform, from 90 to 100 minims. This is the result of careful measurement, with the apparatus fitted up by me for my own use. Its success has been complete, and the allowance here given is considerably in excess of that actually employed in my own cases. At the same time

* Dr. Sansom, Chloroform, p. 9.

it is quite possible that circumstances may arise in which more than these quantities will be required, or in which the evaporating surfaces of the instrument may not have been quite so carefully adjusted as in my own apparatus. If the pangs of labour prove to be unusually severe, or very deep insensibility be required for any acutely painful operation, in such a case it might be necessary to use as much as twice the quantities here given; but in all probability the average allowance per hour is herein fairly represented. Three stoppered bottles, each holding an ounce, or at most an ounce and a half, will suffice, as a rule, for the majority of cases in midwifery practice, and will probably be not more than half emptied for any common case. The accoucheur will, however, remember that he keeps the check under his own eye, and will take care that his patient be kept at, as nearly as possible, the same state of anæsthesia as I recommend—namely, that of a conscious indifference to pain in the first stage, of a conscious insensibility to it in the second stage, and in the third, that of a gentle slumber until the birth of the child. The facility with which these degrees can be attained and sustained, by the use of the index of the apparatus, will only be believed by those who will make a careful trial of it and possess themselves of its capabilities.

In previous portions of this little work I have fully stated my objections to the various forms of inhaling apparatus at present in use. Of these, the safest, indeed the only safe kind, is too cumbrous and inconvenient for practical use in many instances, and it is also too costly. All the other kinds are characterised by an entire absence of any sort of controlling arrangement by which the dose of chloroform could be regulated. Simple as it may appear, I believe that the apparatus used in the system here introduced is the only one by which this can be effected. Cer-

tainly it is the only one by which it has been accomplished with anything like accuracy.

Until the introduction of my first model, no apparatus had ever been made upon the peculiar principle here introduced—namely, the separate vaporization of the anæsthetic fluids, and their administration first, in a consecutive order; and, secondly, in varying proportions. An entirely new system of anæsthetics is thus introduced, and the principles upon which it is based may, therefore, be worth consideration for a moment, before a description of the mechanical adaptations by which they are carried out.

The objects which, in the introduction of this method, I have endeavoured to keep steadily in view, are:—

First. Entire security against the excessive action of either of the anæsthetics.

Secondly. The production of a modified anæsthesia, varying, at the will of the operator, from a mere feeling of exhilaration to the deep unconsciousness requisite for abolishing acute pain.

Thirdly. The power of maintaining this state of anæsthesia at the same degree for any requisite period, or of modifying it to arising exigencies.

Fourthly. The reduction of the dose of chloroform to its lowest practicable point.

Fifthly. The partial substitution for it of a vaporous basis of mixed alcohol and ether, whereby its properties are enhanced and sustained, and its dose diminished without abatement of its value as an anæsthetic.

Sixthly. The counteraction of the heart-depressing power of chloroform, by combining it with a heart-stimulant, and thus obviating some of the most frequent causes of danger in chloroformization.

A considerable experience in the use of the apparatus I have designed enables me to express a not ill-founded hope

that it has really accomplished these varying requirements, and that no more safe or agreeable mode of producing insensibility has hitherto been discovered. I believe that the cases must be rare indeed, if they be possible, in which danger could arise if this apparatus be employed. It is against all experience and experiment to believe that danger can arise from inhaling air containing no more than from two and a half to three per cent. of chloroform, and this is the limit to which I have ever found it necessary to push the powers of my arrangement. In the use of this instrument the medical man is no longer in the dark as to how much of the potent vapour he is administering to his patient, for the index finger points the degree while it regulates the quantity. He has also the satisfaction of being able to give —at any moment of depression, if that arise, as it often does in prolonged anæsthesia—a powerful diffusible stimulus in the alcohol and ether vapour, when the patient would be incapable of taking one in the fluid form.

Its value in the lying-in room can scarcely be questioned. In natural labour there is a wonderful order to be observed in the pains which attend it. Beginning at long intervals, and of no great severity, they recur from time to time in a succession of waves, ever increasing in force and acuteness up to the final agony which ushers the infant into the world. It must surely be unwise to treat with the same powerful agent the earlier pains, which a woman will often willingly endure, as the last, which are so acutely distressing, and sometimes almost intolerable. The only means of meeting this eminent case of varying necessity, has been the rude apparatus of the tumbler, or folded napkin, by which a full and active dose is often given when a smaller would not only suffice, but would actually expedite the delivery. It can scarcely be doubted what would be the choice of the mother in most cases, whether to preserve her consciousness and

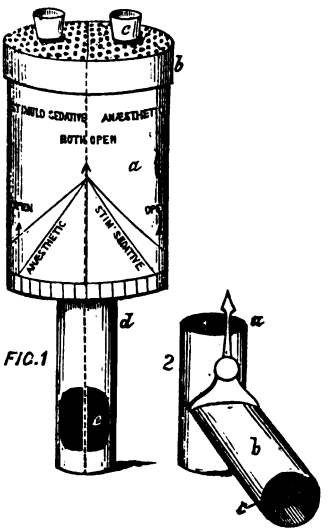
by an almost (or it may be if necessary, a wholly) painless effort bring forth her offspring, or to lie in a heavy stupor, deeper than sleep itself, until the throes of parturition were ended.

In the author's method a mild stimulant and exhilarant effort commences the anæsthesia, and can be sustained simply by keeping the index finger steadily at the required degree. Then, as one uterine wave succeeds the other, the effort and the pain rising together, a slight alteration of the index varies the dose administered, and a gentle insensibility comes over the sufferer, almost like a dream. But the ever-increasing pain requires that this should be deepened from time to time; and by shifting the index a little and little more, this is accomplished, until at last, for a brief period, a full dose is administered during the passage of the head and body of the child. The anæsthetic process is thus completed, and the fourth stage—the expulsion of the placenta—takes place just as the mother is recovering her consciousness, to find her sufferings over and the child born.

I have designed two instruments for carrying out the principles here inculcated. The original apparatus, with which indeed some excellent results were obtained at St. George's Hospital, is represented in the adjoining woodcut, and was fully described in *The Lancet*, of Feb. 10th, 1866, from which I extract the following description:—

"For the mouthpiece I employ Snow's, or any other with a similar valve arrangement. The part of my instrument which is peculiar is the receptacle for chloroform, and the corresponding one for the alcohol and ether. This part consists of two separate pieces, an upper and a lower (Figs. 1 and 2); the upper fitting as in a socket into the vertical part of the lower tube. The upper part consists of a tube (*a*) of a little more than two inches diameter, and is three in height.

It is fitted with a perforated lid (*b*), at each side of which is a small funnel (*c*). This tube is divided through its whole length by a metal diaphragm (*e*), which also runs down into the smaller tube fitted into it at the bottom. The



Figs. 1, 2.

whole forms one compact piece from top to bottom, and enclosing two entirely distinct spaces, one of which is reserved for the chloroform, and the other for the alcohol and ether. These have no communication with each other, but have a common opening of an elliptical figure at the bottom (*e*) of the smaller tube. This smaller tube (*d*) is accurately fitted, so as to work easily round in the vertical piece of the other part (Fig. 2) of the instrument. In so doing it necessarily exposes, according to the direction in which the larger tube is turned, first one side of the opening (say that leading to the alcohol and ether compartment), and then the other,

leading to the chloroform. It is thus seen that we can perfectly control the nature of the vapour allowed to pass into the other part of the instrument, according as we cause it to turn to the right or to the left.

"The second part (Fig. 2) of my instrument forms the receptacle for the socket (*a*) of the first, and carries the vapour up to the mouth-piece. But in order thoroughly to mix the separate vapours before they are breathed, a piece (*c*) of perforated gilt metal is fixed inside the horizontal arm (*b*) of this piece, and the diffusion thus caused, effects a complete mixture before the vapours rise to the mouth. This same horizontal arm carries the index finger, which points to the scale engraved at the upper part of the receptacle, and by its means (the scale having been carefully adjusted by experiment to the openings below) the quantity and the quality of the vapour are at once read off. The rise of the lines exhibits the gradual increase of aperture. The graduated marks answer the double purpose of an index and a safeguard; for the index finger fits into them with a spring, and holds the apparatus at the required degree until it be desirable to shift it farther. The instrument may thus be consigned to a nurse for a time, and the operator feel secure that no excess of chloroform can be accidentally administered."

It may be necessary to explain, that at first I formed the design of naming each compartment after the special characteristic of its vapour, hence the terms seen in the cut, viz.—"stimulo-sedative," as applied to the alcohol and ether; and "anæsthetic," as applicable to chloroform alone. It seemed, however, more simple to give each its proper designation. This original model was found defective in some minor points, chiefly of mechanical construction rather than of principle. And this could scarcely be wondered at, since it was wholly made by my own hands, with

aid of a few ordinary tools. It was, however, seen in operation by Mr. Blaise, of Messrs. Savigny's, and he undertook to carry out my designs with the skilful and excellent workmanship for which his firm is celebrated. In the result the instrument represented in the next cut, Fig. 3, was produced.

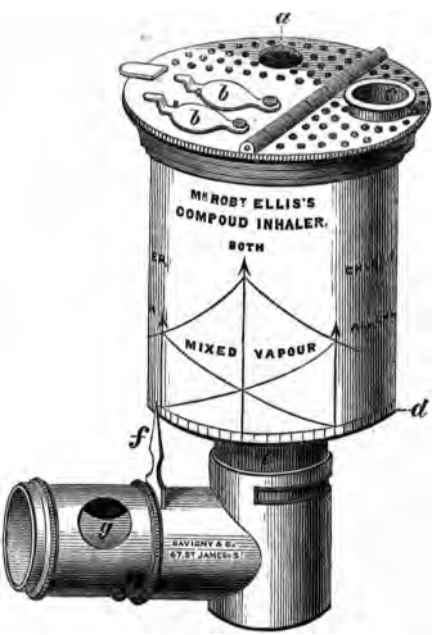


Fig. 3.

In this arrangement I have taken much pains to proportion the chambers for evaporation to the requirements of the accoucheur and the surgeon. Two-thirds of it are devoted to the alcohol and ether (*a* and *b b*), and but one-third to the chloroform (*c*). The alcohol compartment is

separated from that for ether; and by an arrangement of inner partitions, the air is made to course over a very large surface, so as to become fully charged with vapour before its exit. In addition, an air-valve (*g*) was introduced into the horizontal arm, so as to obviate meddling with the valve of the face-piece. The index finger (*f*) points to the graduated scale (*d*), and the instrument revolves in its socket (*e*), as in the former instance. The space between the arrows represents the interval of the mixed vapours, the proportion of chloroform rising in one direction and that of alcohol and ether in the other.

But I must now draw attention to a very peculiar feature in this apparatus, and one to which no small importance must be attached. It is the method by which the evaporation of the ether and chloroform are regulated. The alcohol representing chiefly the vehicle for the others, it appeared to me of the greatest consequence to contrive some simple plan by which only a certain portion of ether or chloroform could be liberated in a given time. In common inhalers, a drachm of chloroform is poured in all at once, over a mass of lint or paper or cotton-wool, and the evaporation is left to its fate. The result is, that the air drawn through has at no time an exact or definite quantity of the vapour in union with it.

After making trial of numerous plans, it occurred to me to imitate the lubricating arrangements adopted in steam-engines and other machines, namely, to pour a definite quantity of the fluid into a little cup, and then to cause it to liberate itself by inserting in it a few strands of cotton wick. The capillary attraction instantly makes itself felt, and the fluid leaves the cup in a beautifully gradual manner. If the reader will take a small minim measure, and pour into it a drachm of ether, and then immerse in it six or eight strands of cotton wick, allowing them to

hang a little over its sides, it will be seen that the ether leaves the measure with great regularity until it is entirely emptied. This simple experiment is so curious and interesting, that it will repay the slight trouble of performing it. With chloroform the same happens, but more slowly. In proportion to the number of the strands of wick is the evaporation and the loss of fluid; and this can be so timed that a definite percentage of either chloroform or ether is given off for every inspiration drawn through the apparatus. Thus, not to detail a number of minor experiments made to settle this point, it was found that, at a temperature of 65°, a test-tube holding one drachm of chloroform, and from which sixteen threads of cotton wick depended, and were made to rest on a few inches of cambric frilling, lost rather more than six minims per minute, in the open air. But this evaporation was nearly doubled in the draught of the inhaler.

Thus an accurate measure was obtained, by which a most complete control could be effected over the escape of these two volatile liquids, and an additional security was afforded against any overdose of either. In fact, it has been the discovery of this simple arrangement which has enabled me to effect such a remarkable economy in the use of the fluids used in the process.

Within the compartment for chloroform, and in that for ether, is fastened a little ring, and into this is dropped a small glass tube having from six (for ether) to eight (for chloroform) strands of cotton wick, hanging down on opposite sides, making twelve to sixteen strands for evaporation. The tube holds about sixty minims. At the bottom of the compartment is a little cambric frilling, placed so as to catch any drops which may fall from the wick. This is the whole arrangement. Immediately that the fluid is poured in, it begins to ascend the wick, becomes exposed

to the inspiratory draught, evaporates, and is steadily replaced by fresh, until the whole is used up. The regularity with which this most simple contrivance does its duty is most satisfactory, and I commend it to any who, not caring to adopt the whole of my principles of anæsthesia, may be glad of an adjustment so perfect in action and so incapable of derangement.

The device by which I have effected the large evaporation of alcohol, according to my views, essential to the system of mixed vapours, has been already alluded to. With a few pieces of brass wire a little cage was made, in miniature representing the arrangement adopted in floor-cloth factories, but really designed from a consideration of the respiratory apparatus of the fish. After much trial, the very best material for evaporating the alcohol was found to be the beautiful cambric frilling made at Coventry, and perfectly free from all "dress." This fabric, an inch in width, was passed alternately over cross-wires at the top and bottom of this little frame, until 50 inches of it were contained in a space not more than three inches in depth, by one inch and a quarter in diameter. Thus hanging in vertical folds, the air inhaled passes over it without impediment; and in its course robs it of the alcohol which is poured on from above. If it be desired, so powerful an impregnation of alcohol vapour can be thus got as to be almost too irritating for use.*

The evaporating surfaces are here adjusted so as to afford, as nearly as may be, an equal amount of vapour from each of the three fluids. The amount of alcohol vapour given off by the above arrangement is, at ordinary tem-

* This description will be better understood by reference to the Figure 5, further on. The woodcuts have been drawn of a somewhat large size (in proportion to that of the page) in order to give the details with greater clearness.

peratures, equivalent to an impregnation of the air passing over it to about two per cent. If stronger than this, it produces irritation of the larynx and cough. The highest possible quantity which can be given off from the chloroform compartment does not exceed three per cent. with the number of strands of wick directed to be used; and the same is true with that of ether. More commonly there is a very equal quantity of all really consumed. The fluids are supplied by a little minim measure to the different compartments, at intervals varying of course with the requirements of the patient. This especially is true in the obstetric use of the instrument. With a little experience, it is easy to find out when either compartment is running short. This may be learnt by smelling the opening of the apparatus; and it is also possible to gain information from the odour of the air expired from the face-piece valve. In *continued* inhalation, for surgical operations, it will be found that a fresh supply, in quantities of about forty or fifty minims, will be required every five minutes at first, and then in less quantities, as the patient succumbs to the anæsthetic influence.

I have contrived several methods by which a constant supply of the fluids can be conveyed from without into the inhaler. in proportion to the waste which occurs by inhalation; and these have been so far useful that they have enabled me to arrive at a standard of consumption, and to equalize it in the various divisions of the instrument. But they are, after all, mere toys, and not deserving of consideration for practical use at the bedside. The apparatus is quite complete as it is here represented; is free from all complications; is handy to use, and, if a little pains be taken to obtain an insight into its principles, it will, I think, prove as good an assistant to my professional brethren as it has been to myself.

But I have not found the instrument in the particular form here shown quite easy to manage for obstetric purposes, although it is excellent for use at an operation, being intended to be held in the hand, and, with the face-piece attached to it, applied to the mouth until unconsciousness supervene. Having no sufficient basis of support, it is apt to turn aside if laid on the bed, and its action

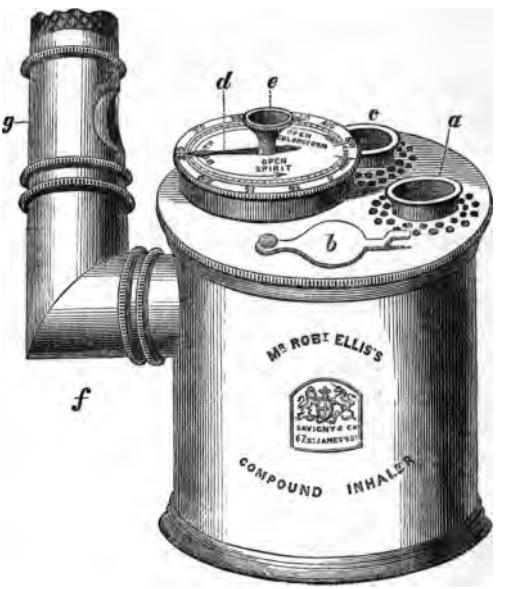


Fig. 4.

is thus interfered with. My object having been chiefly to get a good arrangement for use in the lying-in chamber, I have devised the following instrument, which has been made for me by the same firm, and has proved really invaluable. It is represented in the woodcut (Fig. 4). It consists of a metal cylinder about three inches in height

by two and three-quarter inches in diameter. On one side, near the upper part, the tube (*f*) emerges which conveys the vaporized air from the chambers contained in the cylinder. This elbow tube has attached to it the valve (*g*) for admitting air at the commencement of the process, and it is movable so as to adapt itself to the different positions of the patient. Penetrating the cylinder, it communicates with a small circular chamber, at the bottom of which are two apertures, one connected with the chloroform side, and the other with the alcohol and ether. The different currents of air charged with vapours are thus caused to come together at the bottom of this chamber, and the openings in it are covered by a circular valve perforated in one half, so as to correspond with these openings, and the other half being left blank. A little consideration will show the reader that if this flat plate be turned by a pin passing through its centre, it will, according to the direction of the rotation given to it by the pin, uncover either one or other of the openings, and at one part of its course both will be opened simultaneously. Also that any degree of one opening may be uncovered, or any degree of the other, according as the pin is turned more or less round. For example, all the alcohol and ether opening may be uncovered without uncovering that leading to the chloroform at all; or turned a little more, *that* opening may be slightly, or more, or wide opened, at the will of the operator. Thus, by a most simple mechanical arrangement, we can procure any kind of mixture of the different vapours in any required degree, or beginning with chloroform only, that aperture alone may be kept in use. It is, in fact, difficult to express the remarkable facility for graduating the vaporized air in either one, or the direction which this adjustment affords.

This pin is attached at its upper end to the index finger (*d*), and is worked by a small thumb screw (*e*). The upper

end of the small cylindrical chamber being covered with a metal cap, the index finger lies outside, and on the surface of the cap is engraved a scale precisely corresponding to the rotation of the valve beneath. The surgeon thus sees on this dial, as on the face of a watch, the precise condition of the valve below, and learns from it at a glance what is the nature and quantity of the vapour he is administering to his patient. Only an accident of some very extraordinary kind, or the most gross negligence, could interfere with the working of this index; and such is the arrangement for evaporation, as I have before explained, that even in such an event, an overdose is as impossible as is the explosion of gas by the locked safety-lamp of the miner.

The surface of the dial represents the gradual increase of aperture below, and is divided into equal divisions of five degrees each. I commence inhalation with the index pointing at five degrees of alcohol and ether, the receptacles for these fluids having been previously charged, and the air valve in the elbow is then wide open. After a few inspirations this valve is gradually closed, and the index finger is advanced by single degrees up to ten. This is the point where chloroform influence faintly commences. The index is now moved still more gradually until it marks seventeen or eighteen degrees on the scale. Of these degrees, ten represent the mixed vapour of alcohol and ether, and the remainder that of chloroform. I very seldom find it necessary to advance the index further than this point in a confinement; but for a surgical operation, it will perhaps be necessary to go beyond it, and to give the vapour uninterruptedly from both sides of the apparatus, or if very deep anæsthesia be demanded, then the index must be taken a full half turn onward, so as to give the predominance to the chloroform, and render the alcohol and ether mere auxiliaries. It is satisfactory to know that it is but

seldom that the full power of the apparatus is really required, and it is a great relief to feel assured that at no point is it capable of giving a dangerous dose to the patient. At a point opposite to the elbow is a small space marked "off," indicating that when the finger is at that point, no vapour whatever can leave the apparatus. Thus it can be turned off in the intermission of inspiration, and the waste of the fluids prevented.

The chambers for all three fluids are, as in the former arrangement, quite distinct; but those of alcohol and ether communicate with each other at one point. The fluids are supplied by pouring in a measured quantity through each of the funnel-shaped openings (*a* and *c*) in the lid of the instrument. The aperture for supplying the ether (*b*) is, in consequence of its excessive volatility, kept covered with a shifting metal plate, which is turned aside when the ether is poured in. The chloroform and ether chambers contain the small reservoirs (the test tubes) as in the other instrument, and as these exactly underlie the openings in the lid, it is easy to fill them from time to time as they require it.

It will be seen that from its shape this instrument stands with perfect security, even on an irregular surface. It is therefore excellently adapted for the accoucheur. In my own practice, as shown in Fig. 6, it is connected with an elastic tube to the other end of which the face-piece is fixed: the inhaler thus stands by my side, and all its arrangements are within easy and convenient control. But it may also be held in the hand, dispensing with the elastic tube, and directly fixed on to the face-piece. It is in this condition more handy for use in surgical operations.

Fig. 5 represents a section of this instrument, seen from above, with the lid removed. In this cut *a* shows the cylindrical chamber in which the vapours meet on their

way into the elbow (*b*). At the bottom of this chamber are seen the two apertures leading, the one (*g*) to the chloroform compartment, and the other (*h*) to that for alcohol and ether. The arrangements for evaporation are well shown in this diagram. Thus the letter (*c*) indicates the glass tube holding the chloroform, and out of which the strands of cotton wick (*c* and *f*) are seen issuing, and proceeding to the bottom of the chamber, where they rest

Fig. 5.

on a little cambric frilling. At (*d*) is seen the tube for ether, also provided with its strands of wick; and at (*e*) the upper end of the framework is shown over which the cambric is carried so as to form perpendicular folds reaching to the bottom of this compartment, which is devoted to alcohol. It will be seen from this cut that more than two-thirds of the capacity of the apparatus is devoted to alcohol and ether, and the remainder to the chloroform.

I have given no consideration to the subject of preserving a uniform temperature to the apparatus, since discovering, by a series of careful trials with a good thermometer, that the temperature of the chambers, whatever (within reasonable limits) be that of the air around, is very regularly reduced, by evaporation of their fluids, to from 40° to 45°. And the operation of the instrument in either of its forms is wonderfully equable and regular, possessing also what no other apparatus does possess, a most minute method of adjustment to changing circumstances.

Essentially the principle on which both these forms of apparatus depend for their utility is identically the same. The difference is merely one of mechanical arrangement. Yet I have thought it desirable to offer both kinds to the consideration of my professional brethren. But in my own judgment, the latter is the most perfect, as it is also capable of the most accurate combinations of the different vapours employed. Possibly, however, this opinion may take origin in the fact that in my own case it is more often used for the lying-in room and operations at the bedside than for other purposes. Either of these instruments can be taken to pieces, cleansed, and fitted for inhalation in a few minutes, and they have no parts which can become deranged by use.

The time occupied for inducing insensibility by this apparatus varies from eight to fifteen minutes, according as the patient breathes more or less of the chloroform vapour. It is perfectly possible and safe to obtain anæsthesia in even less than eight minutes, but this time, or even the longer period, is generally preferred by me, on account of the very gradual manner in which we are then able to bring on a condition of unconsciousness. With the supply of chloroform under his finger, it is of course always within the power of the medical man to reduce the period of preparation to

which I attach so much importance. Or, if he prefer it, he may commence at will with chloroform only, proceeding just as with an ordinary inhaler. For my own part I consider the economy of a few minutes as a very small matter in comparison with the security of the process and the well-doing of the patient. These remarks apply only to the anæsthesia for surgical operations, as I have already explained that for obstetric use, the peculiar excellence of this system resides in its gradually increasing intensity proportional to the rise of the degree of suffering in the mother. In the experiments made with the instrument at St. George's, it was found that very little real loss of time was incurred over that consumed in ordinary anæsthetic operations.

The accompanying engraving (Fig. 6) represents the whole arrangement, with the elastic tube and face-piece, exactly as it is used by me at the bedside. The patient holds the mouthpiece in the left hand, and takes from it just as much of the vapour as her feelings may require her to use. The small valve seen in the face-piece gives exit to the expired air, and the vapour is inhaled through the tube which passes under the right arm to the inhaler, resting at the side of the couch. The tube is so large, and all the valves are so free, that the breathing is as easy as ordinary respiration, and is attended with scarcely any conscious effort. The patient is able for a long time by this system to keep the instrument in her own power, using it or not, as she feels disposed. The medical man merely fixes the index finger at the proper degree, and keeps the apparatus supplied with fluid. Seated at the bedside, he can thus observe exactly how much vapour his patient is taking; can regulate not only the quantity but the quality of it, without doing more than simply turning the index, and can admit an abundance of air at any moment by slipping back the

valve in the elbow tube. A little consideration of the perfect control which this arrangement affords on the one hand to the patient, enabling her to satisfy the urgency of her demand for relief, and on the other to the medical man

Fig. 6.

as to the nature and extent of that relief, will, I think, justify the terms in which I have spoken of it.

I have already explained that, as labour pains become more and more frequent and severe, the sufferer requires

an increased proportion of the chloroform to be mixed with the other vapours; and as this increases she then becomes no longer able to keep the face-piece applied to herself. The nurse is then put in charge of it, and keeps it applied until nearly the close of labour, it being removed a short time before the completion of the birth, according to the direction of the medical attendant.

I must here reiterate the strong convictions which much thought on this whole subject has impressed on my mind, namely—first, that chloroform ought not, as a rule, to be given alone, but in combination with a stimulant; and, secondly, that there is no means of accurately administering it, either separately or in combination, but by some mechanical contrivance. Whether these desiderata are best effected by such an arrangement as I have devised or not, must be left to others to determine. But in a profession so essentially practical as ours, it always gives value to an instrument to be able to assert of it, as I can of this, that it has done excellent service in the operating room and at the bed-side, mitigating pain when that was desired, and wholly abolishing it when that too became necessary.

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